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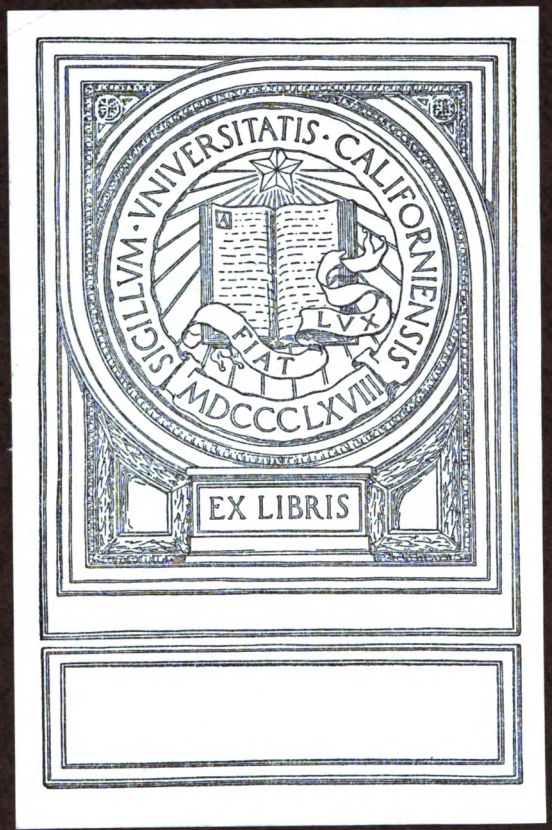

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Presented at the 8th Midwinter Convention of the American Institute of Electrical Engineers, New York, February 19, 1920.

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PRINTING TELEGRAPH SYSTEMS

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ABSTRACT OF PAPER

This paper describes the Creed, Murray Automatic, Siemens & Halske, Baudot and American Multiplex Printing Telegraph Systems, and their methods of operation. A discussion of the operating features of the systems described is dealt with under the following headings:—

Accuracy Under this heading it is shown that printing systems are more accurate than Morse working and that the printing system which permits of sufficient time for checking of messages is likely to be the most accurate.

Speed of Service. It is shown wherein the multiplex systems are superior to the high-speed systems.

Operator Output. Under this heading reference is made to actual results, both at home and abroad.

Maintenance. Outlines method proposed for detecting incipient faults in apparatus and securing uninterrupted service.

Line Economies. The advantages of using the five-unit code are discussed.

Flexibility. Examples are given of the flexibility of multiplex systems in linking up a number of cities, by means of forking repeaters, thereby resulting in either line or operator economies.

THE object of this paper is to describe briefly those printing telegraph systems in use today which are designed for handling traffic at over 100 words per minute, and to discuss their operating features. This minimum speed limitation has been chosen as it effectively divides the various printing systems into two classes as regards traffic carrying capacity, each of which classes is of sufficient interest to warrant treatment in a separate paper. Practically all the printing telegraph systems not considered in this paper have a carrying capacity of from 50 to 70 words per minute, and are consequently in a class by themselves. The systems capable of carrying heavy traffic loads may be divided into two classes.

(1) High-speed systems.
(2) Multiplex systems.

By a high-speed system is meant a system in which the

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sending and recording machines operate at the same speed as the signals are transmitted.

By multiplex, is meant a system in which a plurality of sending machines and a plurality of receiving machines are directly connected in the telegraph circuit and individually operate at a lower speed than that at which the signals are being transmitted.

The systems to be discussed are as follows:

High-Speed Systems. Creed (continental Morse code) tape transmission. Signals received on perforated tape which is fed through a printer. Messages are printed on a tape.

Murray automatic (Baudot or five-unit code) tape transmission. Signals received on a perforated tape which is fed through a printer. Messages are printed in page form.

Siemens and Halske (Baudot or five-unit code) tape transmission. Signals received in printed form on a tape.

Multiplex Systems. Baudot (Baudot or five-unit code) direct keyboard transmission. Signals received in printed form on a tape.

American Multiplex (Baudot or five-unit code) tape transmission. Signals received as printed message in page form.

Several years ago there was a diversity of opinion as to the relative merits of high-speed and multiplex systems, and the advantages of the five-unit code over other telegraph codes were not generally appreciated. The tape-transmitting, page-printing multiplex system using a five-unit code, however, has demonstrated its superiority over all others and one object of this paper is to indicate the reasons for this result.

Perhaps the most elementary form of electric signaling is that in daily use by most executives, where one depression of a push button summons a messenger boy, two depressions means stenographer, and so on, a bell or buzzer being the telegraph instrument of call. To send the 26 letters of the alphabet in this fashion, where one beat represents *a*, two beats *b*, three beats *c*, and so on, would, obviously, be a tedious process. By arranging that some beats are short and some long and forming combinations of these short and long beats, a code can be built up. This is the basis of the Morse code. For actual telegraph purposes the push button is replaced by a suitable key and the bell or buzzer, by a sounder. Fig. 1A.

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The sounder is an instrument which requires a considerable amount of energy to actuate it. Consequently, when a line exceeds a few miles in length it becomes economical to introduce for the reception of the signals, a more sensitive instrument than a sounder, namely, a relay, and to cause the sounder to be actuated locally as shown in Fig. 1B. The relay alone is unsuitable because the noise produced is not sufficiently loud to be heard with distinctness at all times. With such a system, telegraph signalling can be carried on over several

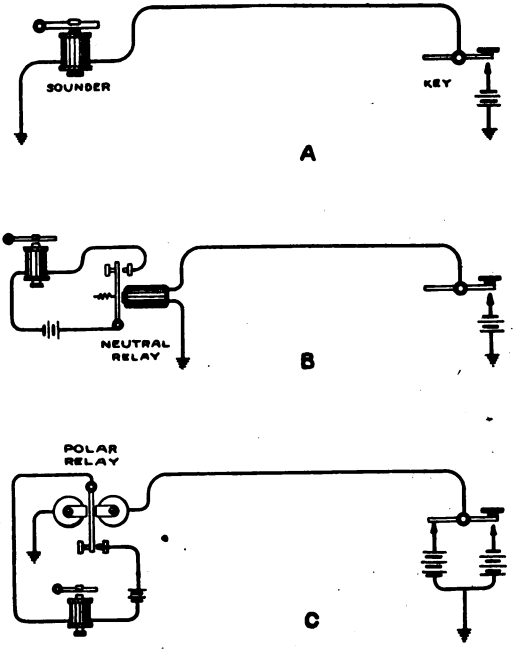

FIG. 1

hundred miles provided the insulation of the line is good. Under wet weather conditions, however, the strength of the operating current at the receiving end of the line is reduced and the relay must be re-adjusted.

If, instead of a relay of the simple "neutral" type, and a single-pole battery, there be used a polarized relay and a two-pole battery, Fig. 1C, the need for readjustment of the relay to meet variable insulation conditions is eliminated. The armature of the polar relay is acted upon in both directions. An impulse from the negative or "marking" battery causes

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the tongue of the polarized relay to make contact with its right hand or marking stop, whilst an impulse from the positive battery reverses its movement.

The positive or "spacing" battery takes the place of the retractile spring in the neutral or non-polar relay. As the current from both batteries is affected equally by variations in the line insulation, this is the equivalent of automatically varying the strength of the tension spring of a neutral relay to the exact degree of adjustment necessary.

Fig. 2 represents oscillograph records of signals transmitted over an artificial line simulating a 400-mile open-wire circuit. *A* shows the signals repeated by a polar relay, and *B* the signals

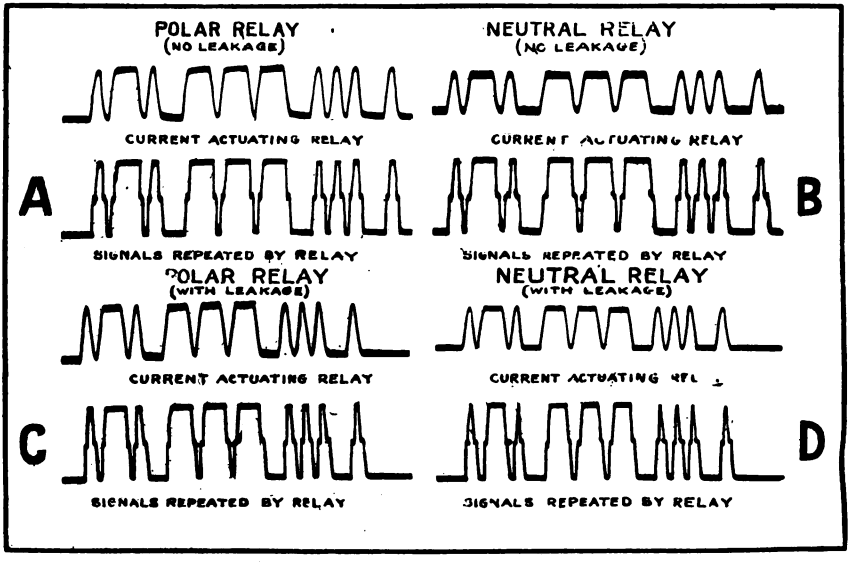

FIG. 2

repeated by a neutral relay when the insulation of the line was perfect. *C* and *D* show the repeated signals by the polar and neutral relays respectively, when the insulation resistance of the line is approximately one quarter of its conductor resistance. No readjustment of the relays was made.

It will be seen that the repeated signals in the case of the polar relay are the same under the two conditions, whilst in the case of the neutral relay reduced current has produced "pin-pointed" dots. The superiority of the double current or polar method is evident.

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A simple circuit of this type, when operated by hand Morse, provides for the transmission of one message at a time at a speed of approximately 30 words per minute. The next advance is to increase the carrying capacity of the circuit by transmitting two messages simultaneously—one in each direction. This was achieved by the invention of the duplex system.

By providing a polar relay having two equal windings, and an assembly of resistances and condensers to simulate the real line, at each end of the circuit, as shown in Fig. 3, signals may be transmitted from station *X* and repeated by the relay at station *Y* and signals from *Y* repeated by the relay at station *X* without interference with each other. The outgoing currents at each station divides equally at the common terminal of the home relay, the paths via the line *L* and the artificial line *A L* having equal impedances. Passing through the two

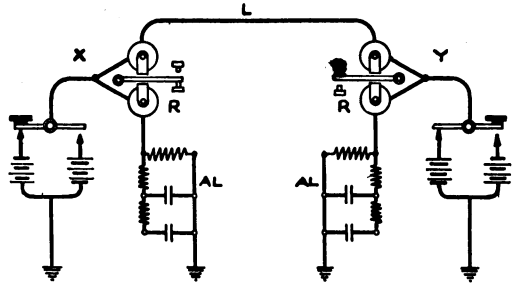

FIG. 3

balanced windings of the home station relay in this manner, they produce no effect on it. When the current reaches the distant station, it passes through the line side winding of the relay *R* and then divides between the two paths to ground, one via the transmitting key and battery, the other through the artificial line *AL*. That part of the current through the artificial line winding of the relay passes in the direction to assist the current through the line winding. The relay, therefore, is actuated in accordance with the polarity and duration of the incoming signals.

Except in the case of the longest duplex lines, it is possible to transmit signals at a speed much in excess of the fastest hand operation. In order, therefore, that a line shall be made to carry an increased load, an automatic transmitter

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for sending and a high-speed tape-recording instrument for reception, are used. Wheatstone designed such instruments in 1858 and these have undergone improvements from time to time, until today, they are capable of operation at a speed of over 400 words per minute. That is to say, the limit of speed of the apparatus is over 400 words per minute. The complete Wheatstone system comprises a perforator, an automatic

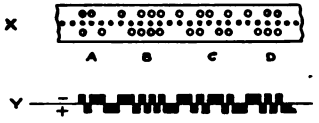

FIG. 4

transmitter and a tape recorder. The original type of perforator has three keys which are struck by small mallets held in the hand. The left hand or dot key perforates two signal holes and a center feed hole in vertical alignment across the tape. The middle or space key perforates a center feed hole, and the right hand or dash key perforates four holes, two being signal holes and two being feed holes. This type of perforator is rapidly being replaced, however, by modern keyboard perforators of which the Kleinschmidt, is probably the best known.

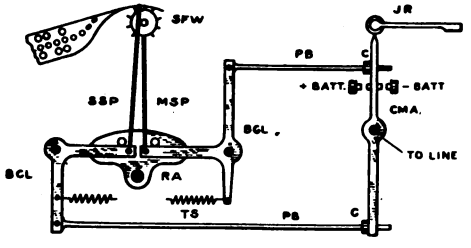

FIG. 5

Fig. 4X shows a piece of tape with the letters *A*, *B*, *C*, *D* perforated.

The automatic transmitter for operation in conjunction with this tape, (Fig. 5) has two vertical selecting pins, each pivoted to a bell crank lever *B C L*. The two bell crank levers control the movements of the contact-making arm *C M A* by means of the push bars, each of which has a collar or flange *C*. Each

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push bar extends beyond the collar, through a hole in the contact lever which acts as a guide or sliding support for that end of the push bar. When pushed beyond the dead center of the jockey roller, *J R*, the jockey roller ensures firm contact being made and also retains the contact lever in the position placed whilst one pushbar is being withdrawn and the other advanced.

The upward movement of the selecting pins *S S P* and *M S P* is controlled by the rocking arm *R A* and by the perforations in the tape. Power is transmitted to the rocking *R A* and the sprocket feed wheel *S F W* from an electric motor and these units of the driving mechanism are so geared that the marking selecting pin *M S P* rises so as to strike the tape exactly opposite a feed hole. When no signal hole occurs the selecting pin is not free to rise, consequently, the contact-making arm remains in the spacing position.

When a signal hole does occur the "marking" selector pin *M S P* passes through it, and the push bar is forced to the right by the tension spring *T S*. As the feed wheel rotates, moving the tape along, the rocking arm releases the spacing selecting pin *S S P* and withdraws the marking selector pin *M S P*. The upper end of the spacing selector pin is so guided as to engage with the signal hole in the lower row on the tape. When a signal hole occurs, the spacing selector pin passes through it and the lower push bar *P B* moves to the right causing the lever *C M A* to make contact with the positive battery contact point.

In the case of a dash or a space, both selector pins are prevented from rising once owing to the absence of signal holes. During these periods, the contact-making arm remains at rest.

During a dash it rests against the negative battery contact and during a space against the positive battery contact. The signals passing to the line are shown at *Y* in Fig. 4.

For a speed of 120 words per minute each selecting pin is freed to rise through the perforations in the paper tape at the rate of 54 times per second, the rest of the mechanism operating at a like rate. Obviously, the adjustments in such a machine must be extremely accurate.

This method of transmission is used in the Creed printing system which was designed to supplement the Wheatstone system and thereby to effect labor economies and reduction

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of delay at the receiving end, two features in which the Wheatstone system compares unfavorably with printing systems.

CREED SYSTEM

This system has been in commercial use in England and several other countries for the last 12 years. Actually it may be described as a development of the Wheatstone system. So far as the sending station is concerned there is no change from the apparatus and method of operation used in the Wheatstone. The messages are first handled by operators at keyboard perforators who prepare them in the form of perforated tapes. These operators are generally seated close to the transmitter, and as they complete each length of tape containing two or three messages, pass it forward to an operator who feeds the tape into the Wheatstone transmitter.

At the receiving station the incoming signals are made to actuate a "receiving perforator" which reproduces a perforated tape identical in all respects to that which is fed into the Wheatstone transmitter at the sending station. This perforated tape is then fed into an automatic printer which prints the messages in bold Roman characters on a paper tape.

The general practise is to have the receiving perforator and printer mounted conveniently near each other so that the perforated tape is fed into the printer with minumum delay.

As the printed tape comes from the printer it is fed through a small gumming device, or if gummed tape be used, over a moistening roller, thence to the gumming operator. The duty of this operator is to paste the tape neatly on the standard telegraph blanks. Where the speed is low, such as on circuits feeding or fed by a submarine cable this operator checks the messages as well, but on circuits operated at 100 words per minute the gumming operator is able to perform only the work of pasting; the checking being done by a second operator. This system is an improvement over the Wheatstone system in that it eliminates the laborious process of tape translation.

Receiving Perforator. Fig. 6 shows in diagrammatic form the construction of the Creed receiving perforator which reproduces a perforated tape identical with that fed into a Wheatstone transmitter at the distant end of the line.

A represents a polarized relay of the British Post Office type. No electrical contacts are used, and in place of the contact-making tongue, a light tongue *R T*, having a small

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slide valve $S\ V$, at its free end, is provided. Movements of this valve $S\ V$ control a supply of compressed air to the small

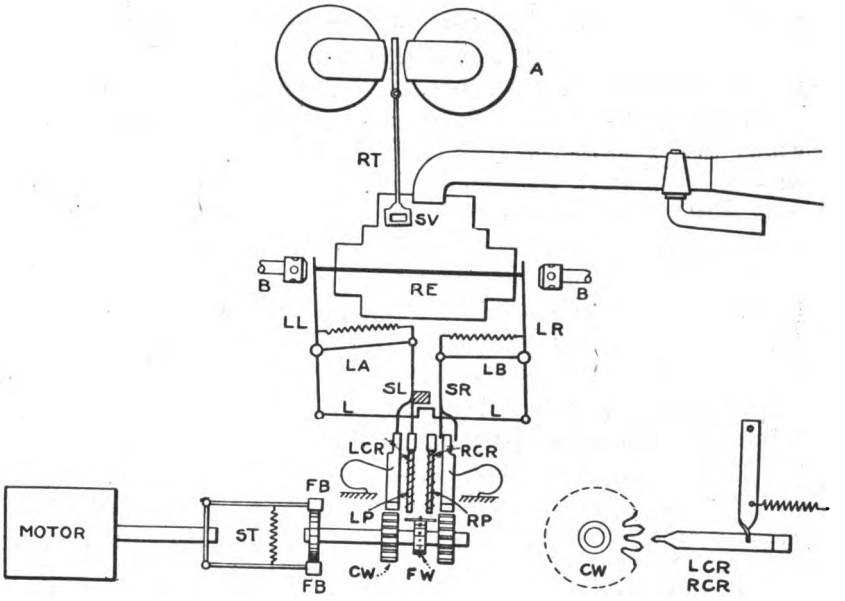

FIG. 6

relay engine $R\ E$, causing its piston to move from side to side. The rod of this piston carries two circular disks which act as

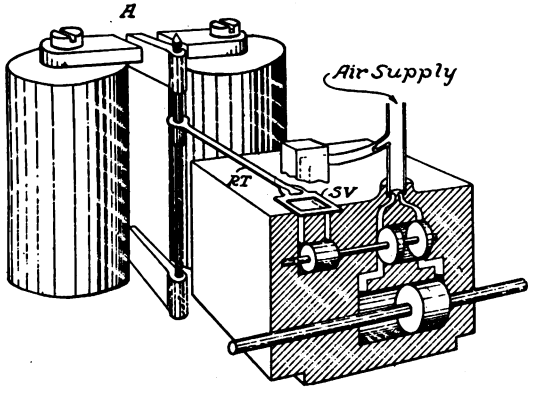

FIG. 7

valves controlling the air inlets to a larger double-acting piston (Fig. 7). This larger piston has a rod projecting from

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each side of it, the rods projecting through the cylinder cover, and acting upon the bell crank levers $L\,L$ and $L\,R$, (Fig. 6). The adjustable buffers B regulate the travel of the piston and piston valves. The arms $L\,A$ and $L\,B$ transmit the movement to the striker arms $S\,L$ and $S\,R$, the free ends of which are bifurcated for the purpose of thrusting against the punches $L\,P$ and $R\,P$ and corrector rods $L\,C\,R$ and $R\,C\,R$. The punches and corrector rods are mounted and guided in a separate block which also carries the die-plates, feed wheel, and corrector wheels. The ends of the corrector rods have flattened pointed ends which enter between the teeth of the corrector wheels. The punches and correctors are the parts most subject to wear and this arrangement provides for the quick replacement of the punch block, there being generally two such blocks provided with each machine. Springs are provided for restoring the punches and corrector rods as shown in Fig. 6.

The paper tape which is previously center-holed is fed up between the die-plates past the punches and engages with the small sprockets of the feed wheel $F\,W$. The feed wheel and correcting wheels $C\,W$ are firmly mounted on the same spindle which is rotated by an electric motor. The corrector rods move in advance of the punches and hold the corrector wheels and the feed wheel in the correct position so that the perforations made by the punches shall be in correct vertical alignment with the feed holes. This ensures that the perforated tape will properly actuate the printer. As the tape is momentarily stopped at the instant of perforating, a friction drive is introduced between the motor and the feedwheel spindle. The exact degree of tension is secured by regulating the position of the spring $S\,T$ along the two rods carrying the friction clocks $F\,B$.

Connecting the ends of the bell crank levers $L\,L$ and $L\,R$, is a link L on which is a tappet piece which pushes on the striker bars laterally, and causes them to slide clear of the corrector rods and punches at the right moment.

As the two signal holes forming a dot must be in vertical alignment with their corresponding feed hole on the tape and a small interval of time elapses between the two perforating operations, during which time the tape has traveled a little, the right-hand correcting wheel and the right-hand punch are given a lead equal to one-half tooth of the corrector wheel.

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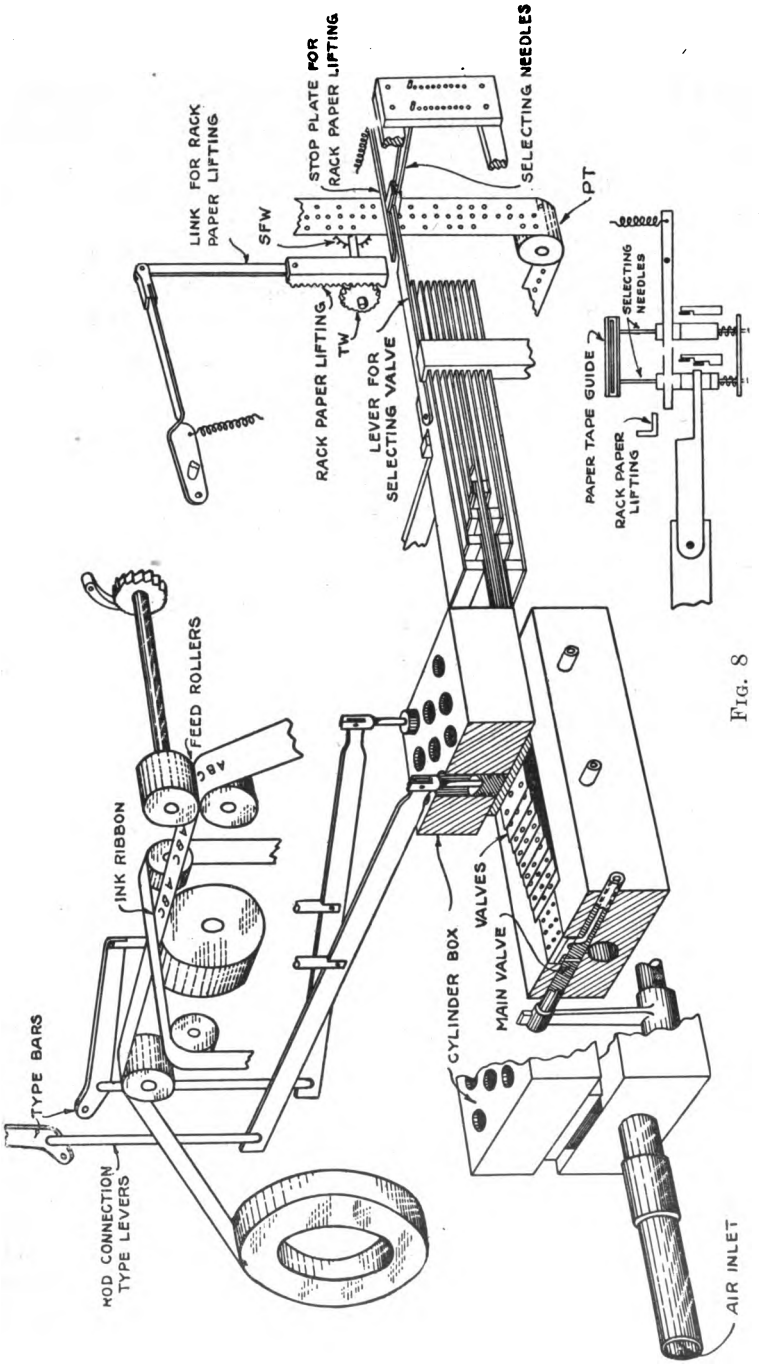

FIG. 8

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Air pressure at approximately 30 lb. per square inch is required to operate the air engine.

The speed at which the paper tape is fed forward may vary within fairly wide limits as the correcting rods will advance or retard it at every signal. On one occasion the writer has witnessed the machine perforating correctly at 140 words per minute while the tape speed was adjusted for 100 words per minute.

When receiving reversals at 120 words per minute, this machine perforates 108 holes in succession per second.

Printer. The perforated tape is next fed through the Creed printer, which reproduces the message in Roman characters on a paper tape, suitable for pasting to a telegraph form. The received perforated tape can be run through the printer several times and, in addition, it can be utilized to re-transmit the signals to any other line or lines equipped with Wheatstone apparatus. Pneumatic pressure is used for the printing and a small electric motor supplies the necessary power to drive the camshaft.

The perforated tape is fed forward, letter by letter, in a guideway, in front of a series of ten pairs of selecting needles, one needle of each pair being associated with one of a series of ten slide valves. These valve plates, made of thin sheet steel, can be made to occupy one of two positions, selected and non-selected, so that a number of different combinations can be set up. Each valve plate has a number of holes or perforations in it and when a combination has been set up, a passage exists through the ten valve plates to one of the small cylinders in the cylinder box. Compressed air can thus be admitted forcing up the small piston which acts on the end of a lever connected to one of the type bars.

A diagrammatic sketch of the printer is shown in Fig. 8. The perforated tape *P T* is fed by means of a sprocket feed wheel *S F W* between two vertical guide plates which have ten pairs of holes positioned to permit of the entry of the ten pairs of selecting needles. Should the perforated tape have a continuous series of dots all the selecting needles would have entry. Particular combinations of perforation in the tape will permit only certain of the selecting needles to enter, and it is by this means, that the spacing and letter selections are made. The feed wheel is mounted on the same spindle as the toothed wheel *T W* which is rotated by the vertical feed rack actuated by

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a cam on the main shaft. An examination of the perforated tape, Fig. 4, will show that between each letter combination there is a clear blank space which would block the entrance of one pair of selecting needles in the same horizontal plane also that the lower row of signal holes alone is sufficient to differentiate between the various letters, figures and punctuation marks, provided that the spacing between the letters is recognized. These are the two underlying features upon which the selecting mechanism of the printer is designed.

If a space occurs in the tape neither of the pair of selecting needles opposite this position will find entry through the guide plates, and will consequently permit the space lever which they control to remain in position to block the downward movement of the feed rack. If a space position occurs opposite, say, the sixth pair of needles, the rack will move down to that position so that on its upward movement it will cause the toothed wheel and feed wheel to rotate and carry forward the tape an equal distance. If the space occurs opposite the second pair of needles, which would be the case for the letter *e*, then the tape is fed upwards two space holes.

If one or both of the needles of a horizontal pair finds entry through perforations in the tape, the space lever is moved clear of the feed rack.

The valve selecting levers are controlled by the selecting needles which engage with the lower row of signal perforations only. When one of these levers is pushed forward by a selecting needle, it is in position to be moved laterally by the rack which has a lateral motion imparted to it at the right moment, by a cam.

Although selecting needles below a space position enter the signal holes of the next or part of the next letter combination on the tape, and carry with them the valve selecting levers, these levers are not acted upon by the rack because it does not descend so far.

Consequently, only those selected levers above the space position are moved to the left and they carry with them the slide valves to which they are fixed.

As soon as the slide valves have been moved they are compressed between the two stout plates forming the slide-valve chamber. The main air valve is then opened by cam action, admitting compressed air to the slide-valve chamber, whence it finds passage through the ten valve plates by the one hole

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made available by the particular valve setting, and forces up the small piston which actuates the corresponding type lever.

The slide-valve chamber is then opened, and the valves are returned to normal position. Meanwhile the paper-lifting rack is drawn up by cam action and in its upward moment it engages the toothed wheel $T\ W$ so that the paper tape is drawn up the proper distance for the selection of the next letter. The path of movement of the rack forms a narrow rectangle, the length of which is determined by the length of space occupied on the tape by the letter combination printed.

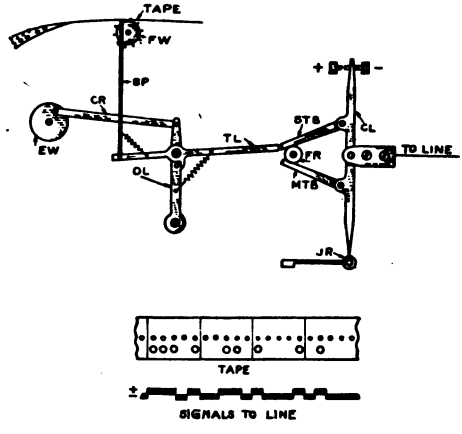

FIG. 9

It will be seen that the differential feed of the tape involves a selecting mechanism which is not required in the case of systems using an equal unit code, which are described later.

This printer has been operated in laboratory tests up to 130 words per minute, but for commercial use it is found best to work it at a speed not exceeding 100 words per minute.

The air pressure required is the same as for the perforator.

MURRAY AUTOMATIC SYSTEM

The Murray Automatic System is not widely used, but where it has been installed it has rendered good service.

At the transmitting station the method of operation closely resembles the Creed. A number of operators perpare the messages on paper tapes by means of keyboard perforators. This tape has feed holes identical with those on the Wheat-

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stone tape, but with signal holes in alignment with the feed holes, on the lower side only. The perforated tapes are passed to the transmitter operator who feeds them into the transmitter.

At the receiving station the messages are received on a receiving perforator which produces a perforated tape identical with that fed into the transmitter at the sending station. This tape is then passed into an automatic printer which prints the messages in page form ready for delivery. In addition to the advantage of the shorter code used this system eliminates the gumming process as used in the Creed.

Fig. 9 shows the appearance of Murray automatic tape. In this case, every letter and symbol occupy the same length of tape (one-half inch) so that a differential tape feed feature is eliminated in the perforator, the tape being fed forward through the perforator letter by letter. Only five punches are needed, all combinations being formed by various groupings of these.

The vertical marks on the tape after every fifth hole are for the purpose of enabling the operators to read the signals.

The transmitter is driven by a phonic wheel motor which is controlled by a vibrating reed. The unloaded reed is designed to vibrate at a certain speed and by loading it with weights, which can be fixed at any position along the reed, the speed can be reduced. The speed of the transmitter can be adjusted by this means over a considerable range.

In the Murray automatic transmitter (Fig. 9) only one selecting pin $S\ P$ is needed. The tape feed wheel $F\ W$ is coupled direct to the phonic wheel motor whilst the eccentric wheel $E\ W$ is geared to rotate at ten times the speed of the feed wheel, that is, once for each sprocket of the feed wheel. For each rotation of the eccentric wheel $E\ W$, the oscillating lever $O\ L$ makes one complete movement, carrying with it the thrust lever $T\ L$. If there be no signal hole in the tape, the selecting pin $S\ P$ does not rise so that the thrust lever $T\ L$ strikes the upper or spacing thrust bar $S\ T\ B$ and carries it past the dead center point of the jockey roller $J\ R$. The contact lever $C\ L$, therefore, makes contact with the right-hand battery contact point.

At the next step of the feed wheel $F\ W$ the eccentric wheel $E\ W$ makes another complete revolution and the thrust lever $T\ L$ again moves to the right. If no signal hole exists movement of the thrust lever $T\ L$ will be identical with its previous move-

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ment. The contact lever, however, remains in the position set by the previous thrust, due to the jockey roller *J R*.

If the next step of the feed wheel brings a signal hole in line with the selecting pin *S P* the thrust lever *T L* will be tilted downward and will strike the lower or marking thrust bar *M T B* and cause the contact lever to make contact with the other pole of the battery.

With this transmitter operating at a speed of 120 words per minute the pin selecting mechanism is required to operate at the rate of 60 times per second, that is, the eccentric wheel *E W* makes 60 revolutions and the thrust lever oscillates 60 times per second.

Murray Automatic Receiving Perforator. The circuit arrangements of the Murray receiving perforator are shown in Fig. 10.

The vibrating reed *V R* is provided with a weight *W* fixed at some point along the reed so that the rate of vibration of the reed will be slightly faster than twice the frequency of the incoming signals. The reed is kept in constant vibration by means of the local battery *L B*, the circuit being via the contact *V*, the vibrating magnet and the back or front contact of the governing relay. The amplitude of vibration is limited by the buffer springs *B S*. If the amount of energy acting upon the reed be increased, the rate of vibration increases. Conversely, if the amount of energy be reduced, the rate of vibration is reduced. The punching and governing relays are connected in series from the *M* or marking contact of the line relay. The punching magnet is operated when the tongue of the punching relay is pulled up and the contact *P* on the reed is closed. Consequently, if the tongue of the line relay remains in the marking position the punching magnet will be operated each time the vibration of the reed closes the contact *P*. The spacing magnet is operated, when the *S* contact of the reed is closed. If no signals are passing the spacing magnet continues to feed forward the tape, but after about a foot of blank tape has passed an automatic switch *A S*—a small mechanical device—opens the circuit of the spacing magnet *S M* and the tape is stopped. The first marking signal closes this switch and it remains closed so long as signals are passing. The actuation of the spacing magnet operates the escapement mechanism on the motor drive shaft *M D S*. It will be obvious that the punching and spacing magnets

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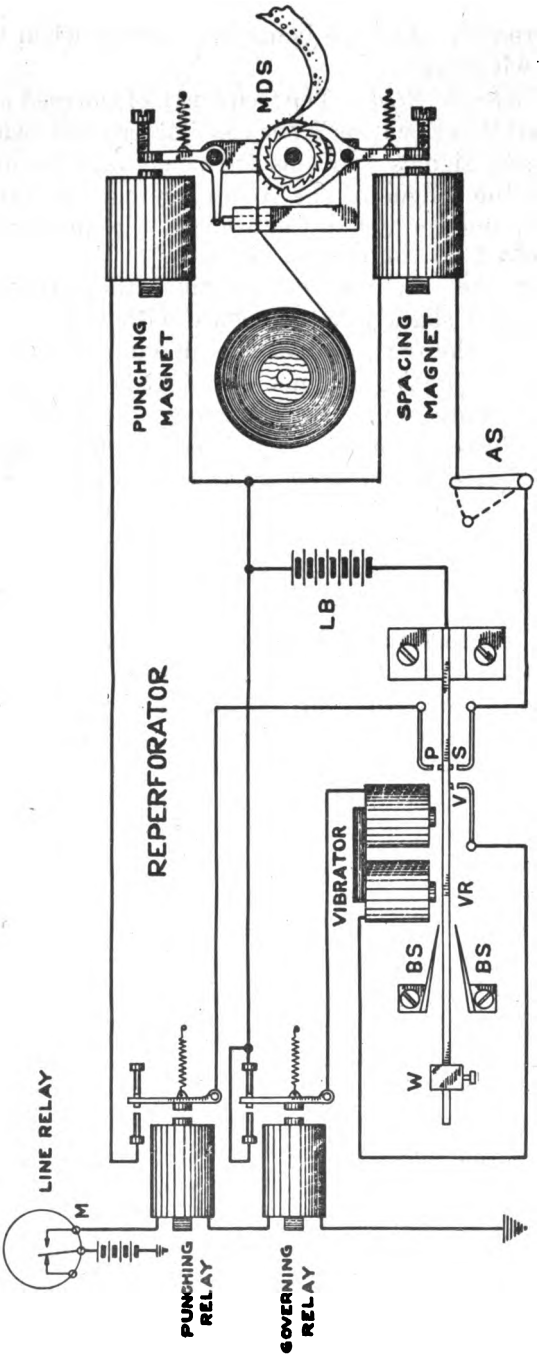

FIG. 10

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work alternately, the tape being fed forward when the punch has been withdrawn.

Speed Control of Reed. The frequency of the reed is adjusted to be about 2 per cent or 3 per cent faster than twice that of the incoming signals and this frequency will be maintained so long as the tongue of the governing relay is stationary or moves from one contact to the other at the same instant that the V contact on the reed is closed.

Actually, the incoming signals cause the governing relay to be operated slightly out of phase with the closing of the contact V on the reed, so that the amount of energy passing through the vibrating magnet is reduced until the contacts are again simultaneous. Consequently, the frequency of the reed is reduced momentarily. When signals are passing, speed correction of the reed by this means may take place about two or three times per letter signals if such be necessary, but generally the speed of the reed is such that one correction per six or seven letters is sufficient to maintain unison.

Printer. The latest type of Murray high speed printer comprises six horizontal slotted combs, five of which have a selecting needle fitted on one end for engaging with perforations in the tape. The sixth comb has no selective needle. Mounted in front of the slotted combs is a series of vertical selecting bars. A small electric motor drives the main shaft which extends across the whole length of the base and all movements are controlled by a series of cams mounted on this shaft.

The tape is fed round a wheel which acts both as a feed-wheel and a guide for the selecting needles.

The type bars are only 2 inches in length and in order to have them all strike at the same position on the platen they are mounted in a circle. Connecting rods are led down from the typebars to a series of hooks one of which is positioned in front of each vertical selecting bar.

The tape wheel is advanced against the selecting needles so that those which find a blank in the tape are pushed to the left leaving the selected needles with their slotted combs in place. The next movement in the cycle of operation is the withdrawal of the restoring bar permitting all vertical bars to move forward, but only one vertical bar finds a free path to move, the others being stopped by the blank portions of the slotted combs. The bar so selected, pushes forward the hook immediately in front of it, placing it in the path of the

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striker bar. As soon as the striker bar comes down, and engages with the hook the restoring bar pushes back the vertical selecting bar so that the setting up of the next letter combination may be proceeded with. This overlapping of the cycle of operation is a distinct advantage permitting a slower operation of moving parts and consequently less wear and tear.

With five slotted combs only 31 combinations can be made, but by adding a sixth comb, which can occupy one of two positions, the number of selections can be doubled. Only 56 selections, however, are required. The sixth bar is moved

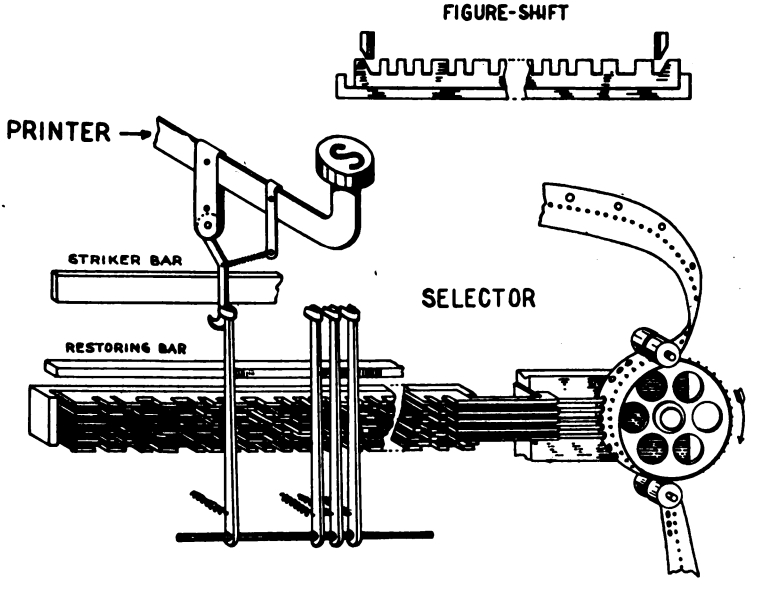

FIG. 11

when the "figure shift" signal occurs in the tape. The vertical bar selected by this signal combination causes the sixth slotted comb to slide in the same way as do the five selecting combs and in this position all the vertical selector bars associated with lower case characters are rendered non-selectable whilst the vertical bars associated with the upper case characters may now be selected. The "letter shift" signal restores the sixth slotted comb to normal.

Fig. 11 shows the selecting mechanism of the old Murray automatic printer, which does not differ fundamentally from

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that of the new high-speed printer. In the new machine, however, typewriter keys are not provided.

Siemens & Halske High Speed System

The Siemens and Halske is another type of high-speed system.

At the sending end the operations are practically identical with those of the Creed and Murray Automatic in having several perforating operators and one transmitting operator.

At the receiving station the perforated tape is eliminated, the messages being printed on a tape direct from the line signals. This tape is pasted on the message blanks.

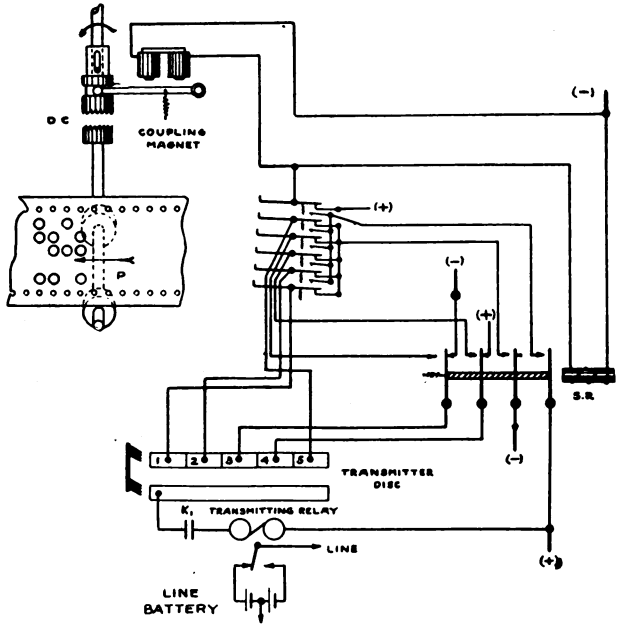

Fig. 12

This system shows a further development in that the intermediate process of perforating a tape at the receiving station is eliminated, but the gumming process is continued.

Fig. 12 shows the high-speed transmitter, used in the Siemens and Halske printer system. The tape in this system is perforated on a keyboard perforator. The five-unit code is used, so that a maximum of five perforations is required per letter combination. The tape, however, differs from the Murray Automatic tape in this respect, the signal perforations are

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made across the tape instead of along it, so that a space of only 0.1 in. per letter is required, a wider tape being used.

With this form of perforated tape the transmitting mechanism must include means for securing the proper sequence of signals. This is achieved by using a rotating distributor which consists of two metal rings over which contact brushes pass at the rate of one revolution per letter. One ring is solid, the other is divided into five equal segments.

Fig. 12 shows the general arrangement of the transmitting circuit. The perforated tape has two rows of feed holes for ensuring its accurate movement over the six contact fingers which are located below the tape. When blank tape is being fed through the transmitter, the centrally pivoted fingers are held down by the tape so that they rest against their upper contact stops.

When no tape is in the transmitters all fingers are free to rise, and the sixth or top finger then closes a circuit through the coupling magnet and the switching relay $S\,R$. Actuation of the coupling magnet withdraws the clutch $D\,C$, thereby stopping the transmitter. The function of the switching relay will be referred to later.

In rising, the five selecting fingers which engage with the signal perforation in the tape, make contact with their lower stops. The upper contact stops are connected to the positive pole of the local transmitting battery and the lower stops to its negative pole. The five selecting fingers are connected to the five segments of the transmitting ring. The selecting fingers are not in lateral alignment; the second finger is 0.020 in. to the left of No. 1, No. 3 is 0.020 in. to the left of No. 2 and so on, so that as the tape is drawn over them they engage with the perforations in sequence and No. 1 engages immediately after No. 5 has engaged with a perforation of the preceding lateral group of perforations. The distributor brushes are so geared that at the moment finger No. 1 engages with a perforation the brushes start to sweep over segment 1; when finger No. 2 engages with a perforation the brushes start to sweep over segment 2 and so on. The solid ring which is in connection with the segmented ring through the rotating brushes is connected through a condenser to the transmitting relay. Consequently, when a perforated tape is inserted and the selecting fingers are set up in different combinations, posi-

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tive and negative impulses will pass through the transmitting relay and actuate it.

When no tape is in the transmitter the transmitting relay would remain at rest, sending out either a steady positive or negative current. As the system is a synchronous one and the maintenance of synchronism between the two ends of the line is dependent upon the reception of signals, provision is made for sending a signal once per revolution in the following manner:

The switching relay is actuated when there is no tape in the transmitter, as has already been described. The actua-

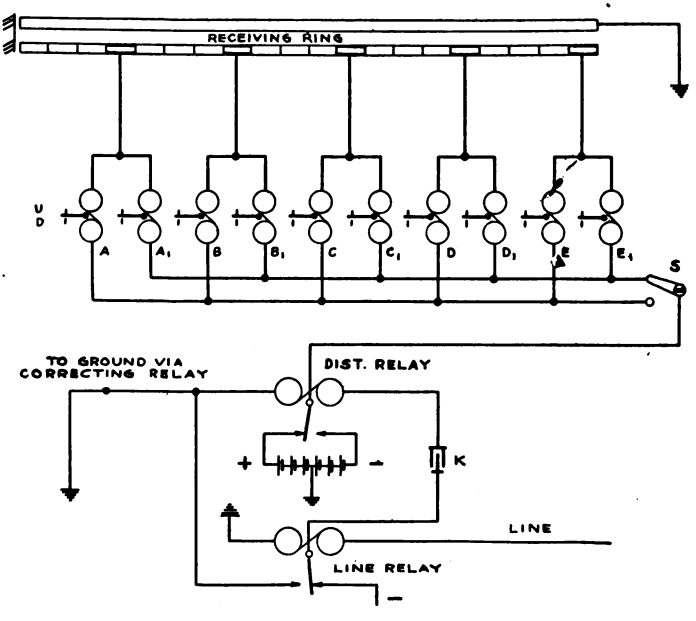

FIG. 13

tion of this switch removes the normal battery connection to the selecting fingers and connects negative battery direct to segment 3 and positive battery to segment 4 of the distributor.

Consequently, the transmitting relay will send out a reversed pulse each time the brush sweeps over segment 3.

Receiving. The receiving apparatus of the Siemens and Halske system comprises a distributor with rotating brushes which make one revolution per letter.

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One noteworthy feature of the system is the use of storing relays which provides an overlap arrangement.

Fig. 13 shows the line and local relays with the receiving ring of the distributor and the storing relays. The storing relays are polarized and are arranged in pairs as shown. The switch S is reversed mechanically at each revolution so that relays a, b, c, d, and e are connected in sequence to the tongue of the distributor relay for one revolution and relays a', b', c' d' and e' for the next.

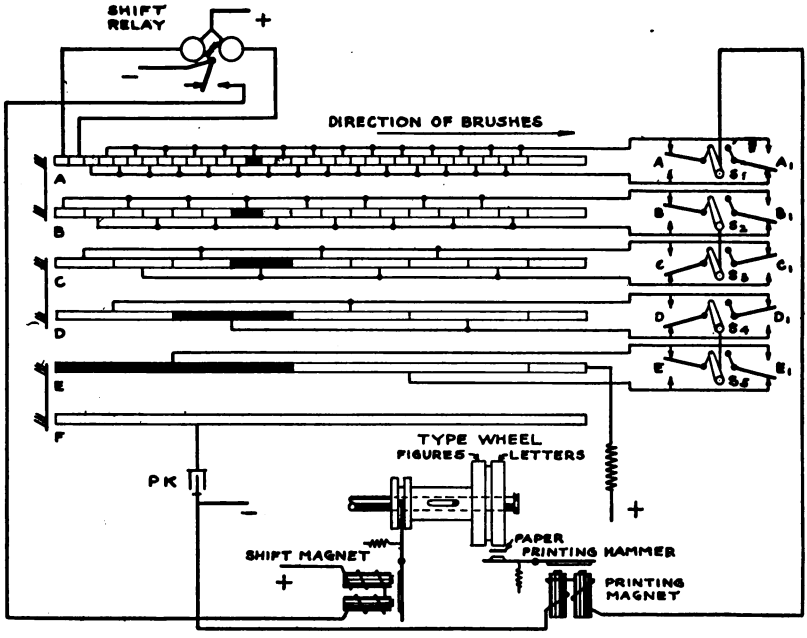

FIG. 14

The distributor relay is actuated from the tongue of the line relay through the condenser K and follows the movements of the line relay. During the reception of signals forming one letter combination the brush makes one complete revolution. Assuming the armature of the relays move to the "up" or U position when a positive impulse passes, and to the "down" or D position when a negative impulse passes, then a letter combination, say $+ + - - +$, would cause the armature of relays a b and e to move to the up position and the tongues of relays c and d to the down position. Being polar relays the tongues

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remain in the position set until reversed by an impulse of opposite polarity.

At the next revolution the next combination would be set up on relays, a', b', c', d' and e'. Meanwhile, the set-up on the relays a, b, c, d, and e is used to effect the selection and printing of the previous letter.

Fig. 14 shows the translator portion of the distributor. It comprises six segmented rings. These are connected to the contacts of the storing relays shown in the preceding figure. The tongues of each pair of relays are connected to switches S_1 S_2 S_3 S_4 and S_5, which are reversed once per revolution, the reversal taking place whilst the brushes sweep over the short blank portion of the rings.

The brushes are mounted on the same shaft as the typewheel and the letters are arranged around the periphery of the typewheel to accord with the code used.

As the brushes sweep over the blank portions of the rings, the condenser PK is charged by being connected across the + and − poles of the battery. The operation of the translator will readily be understood by following the selection of one letter. Assume that the switches are in the position shown and that the tongues of relays a, b, and e are "up" and those of c and d are in the "down" position as shown in the figure. The segments which are involved in this particular selection are shown in black. It will be seen that when the brushes reach segment 14 of the first ring a circuit is provided for the discharge of the condenser PK through the printing magnet. This magnet is actuated, causing the paper tape to be impressed against the typewheel.

The typewheel carries two series of characters, one being letters, the other figures and the usual punctuation marks. In the normal position the letter series is in position for printing and by sliding the wheel along its shaft the figure series is brought into the printing position.

The positioning of the typewheel for printing letters or figures is effected by a shift magnet which is controlled by a differentially wound polar relay. Two of the 32 segments of the first ring are connected to the windings of this polar relay so that the position of its tongue is determined by the "figure shift" and "letter shift" signals which are transmitted over the line.

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Maintenance of Synchronism. Between each of the five short receiving segments of the receiving ring, there are three correcting segments as shown in Fig. 15. As the signals are being received by the line relay, the brush which sweeps over this ring should be on one of the C segments, at the moments when the line relay tongue moves from one contact to the other. Under this condition, the center portion of each signal impulse is utilized for the actuation of the storing relays. If the brush is on an R correcting segment, it is in advance of its correct position and must be retarded, if on an A segment it means

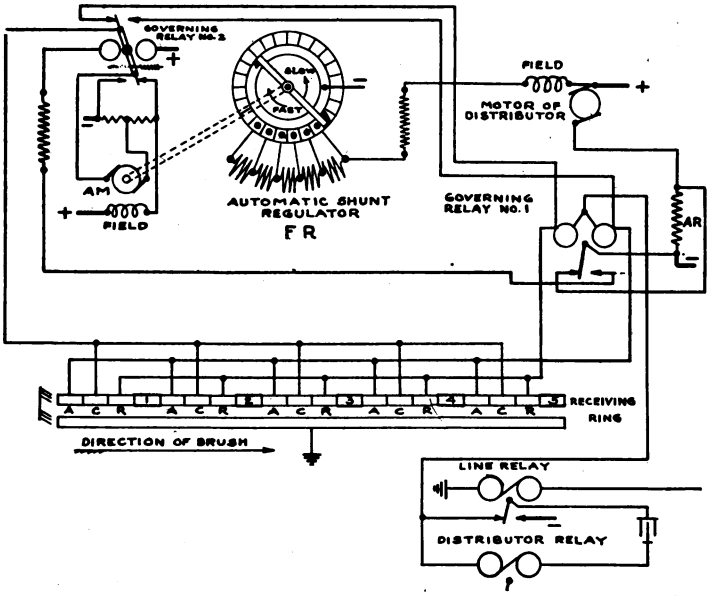

FIG. 15

that the motor has been running slow and must be accelerated.

The speed of the motor which carries the brushes is governed by a resistance $A\,R$ in series with its armature and an automatically adjusted resistance $F\,R$ in series with its field winding. If the motors at the two stations are running at approximately the same speed, the intermittent shunting of the resistance AR is sufficient to maintain synchronism. The field resistance $F\,R$ is used to control wider speed variations.

When the two motors are running in synchronism the operation of the correcting circuit is as follows:

Assuming the armature of the line relay just makes contact

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with its right-hand contact when the brush reaches the first *C* segment of the receiving ring a negative current impulse will pass through the distributor relay to the mid point of the windings of the No. 1 governing relay, through the left-hand winding of this relay to the left-hand contact and upper tongue of the No. 2 governing relay via contact *C* to ground. The armature of No. 1 governing relay will be moved to the right, thereby closing a circuit from the negative pole of the battery through the No. 2 governing relay and also inserting the resistance *A R* in series with the armature winding. The position of the No. 2 governing relay armature is thereby reversed, so that when the brush reaches the second *C* segment the circuit from the negative pole will be through the distributor relay to the mid point of the windings of No. 1 governing relay, through the right-hand winding of this relay to the right-hand contact and upper tongue of No. 2 governing relay, to ground via the second *C* segment. The No. 1 governing relay is reversed, the resistance *A R* is again short-circuited and the armature of No.2 governing relay which is normally biassed is restored to the position shown in Fig. 15.

So long as the brush is on a *C* segment, at the moments when the line relay armature is just making contact with the negative battery the armatures of the two governing relays will move from one contact to the other. The resistance *A R* will be cut in and out at each movement of the armature of No. 1 governing relay. The lower tongue of No. 2 relay, which is insulated from the upper tongue, controls the direction of the current through the armature of the small auxiliary motor *A M*, so that if this lower tongue moves rapidly backwards and forwards the armature of the motor merely oscillates. If, however, the power connections to this motor remain undisturbed for a few seconds, the armature commences to rotate and cause a change in the resistance *F R* which is in series with the field of the larger motor.

Should the brush be on an *R* segment, the current impulse through the condenser and the distributor relay will be via the left-hand winding of the No. 1 governing relay to the *R* segment, across the brush to ground. The tongue of the No. 1 governing relay will move to the right, opening the shunt across the resistance *A R* and thereby producing a slight reduction in the speed of the motor.

If the brush is on an *R* segment, when the next correcting

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impulse is generated the two governing relays will remain undisturbed. Consequently, the resistance $A\,R$ remains in circuit. Should this condition continue for several successive revolutions of the brush, the auxiliary motor will have time to rotate and to aid in retarding the speed of the motor by cutting out resistance in series with the field.

In the event of the brush being on A segments, when correcting impulses are generated, the No. 1 governing relay armature will move to the left-hand contact and shunt the resistance $A\,R$, whilst the position of the No. 2 governing relay will reverse the direction of rotation of the auxiliary motor should the lagging of the brush continue.

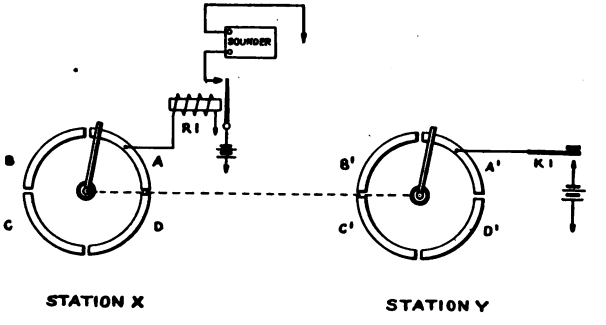

FIG. 16

The auxiliary motor shaft is connected to the adjustable rheostat arm by means of a worm reduction gearing.

This system is operated under duplex conditions. Although provision is made for securing a maximum speed of about 160 words per minute, the normal working speed is about 120 words per minute in each direction.

MULTIPLEX SYSTEM

Multiplex printing telegraph systems are all based on the Baudot system which was invented in 1875 by Emile Baudot, a Frenchman.

The principle of the multiplex system is illustrated by Fig. 16.

If two metal rings be each divided into four segments of uniform length, and contact brushes, connected by a wire, arranged to rotate in synchronism, then segment A at X will be in electrical connection with segment A^1 at station Y, during one quarter of each revolution of the brushes; segment B will be connected to B^1 for a like interval of time and so on.

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Communication by automatic Morse could be carried on, but it is obvious that the speed of rotation would have to be such as to permit of the longest Morse signal combination being transmitted from each segment. There would consequently be considerable loss of time when sending the short length signal combinations. Transmission of one word per segment would be equally unsatisfactory as words vary in length. Obviously, if there is to be no lost time, each signal combination representing a letter or symbol should occupy the same length of time in transmission. In order to obtain sufficient signal combinations to represent the letters of the alphabet, it is necessary to divide this time interval into five units, and arrange that during each time unit a selecting or non-selecting impulse shall be transmitted over the line. This arrangement will provide 32 possible combinations. By adopting "upper case" and "lower case" characters, as is done in typewriter practise, and arranging that two of the signal combinations shall automatically shift the printing mechanism, so as to print "upper case" or "lower case" characters, the number of selectable characters is practically doubled.

In completing this simple arrangement two things are essential:

(1) Means for keeping the two rotating brushes in synchronism.

(2) Means to change the keyboard set-up so as to send a fresh letter combination at each revolution.

Synchronism may be maintained in the following manner:

Assuming 20 segments are to be used for actual signalling, two extra segments are provided at each end. In Fig. 17, these extra segments are numbered 21 and 22. Segment 21 at the sending station is connected to a battery. Segment 22 at the receiving station is connected to a relay.

The brushes are driven by electric motors, the speeds of which are so adjusted that the brush at station X rotates slightly faster than that at station Y, say about $\frac{3}{4}$ deg. or 1 deg. per revolution. When the brushes are started off in synchronism, they will sweep over like numbered segments at the same moment. The brush at station X, however, will gradually gain so that whilst the Y brush is still on segment 21, brush at X will be on segment 22. When this condition exists, an impulse will flow from the correcting battery at Y

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connected to segment 21 through the correcting relay at X. If it be arranged that the actuation of this relay shall slow down momentarily the speed of the motor at X or else by mechanical means retard the brush, the two brushes will again be in synchronism. By this arrangement the duration of the braking effect can be made proportional to the amount of retarding required.

With the arrangement of segmented rings, as shown in Fig. 17, it will be obvious that, as the brush at the corrected station must be slightly out of phase with the incoming correcting impulses, before correction can take place, it will be out of phase with the incoming signal impulses. Consequently, an

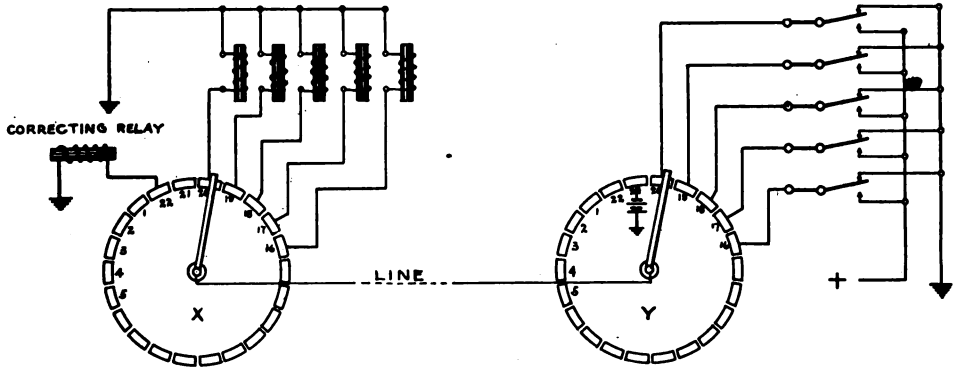

FIG. 17

impulse which should flow say, via segment 17 to the selecting relay connected thereto, may overlap and flow via segment 18 to another selecting relay. The overlapping portion might be sufficient to actuate this selecting relay and thus produce defective selection. This is obviated by using small segments for the receiving ring so that only the middle portion of each signal impulse is utilized to actuate the selecting relays. Fig. 18 shows receiving ring segments of half the length of the sending segments; a represents signals in synchronism in which case the middle half of each signal impulse is picked out for actuation of the selecting relays, b represents the case where the brushes are ahead of their correct position, and c represents the reverse condition. It will be seen that only approximate synchronism is necessary to ensure that the impulses shall be switched to the correct selecting relays.

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This feature of utilizing only the middle portion of each signal impulse is advantageous also in permitting the system to be operated with signals which are considerably distorted. Such distortion may be caused by the electrical characteristics of the line, or by extraneous interference such as induction from other circuits.

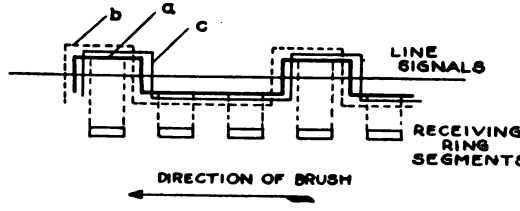

FIG. 18

BAUDOT MULTIPLEX

The Baudot Multiplex System was invented in 1875 by Emile Baudot, a telegraph operator in the French service. Despite the fact that it was put into commercial operation over

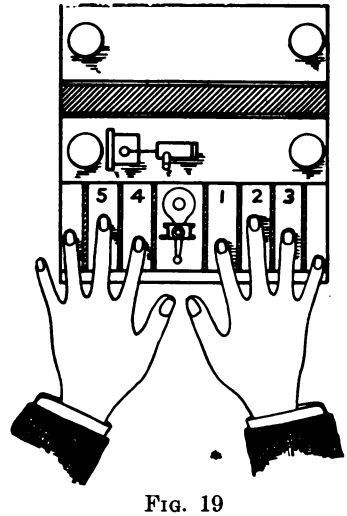

FIG. 19

40 years ago it held the field against all competitors until recent years.

Next to the conception of the multiplex principle as embodied in the Baudot, perhaps the most important development was the doubling of its carrying capacity by adapting it for duplex

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operation, which was successfully accomplished in 1910 by Mr. A. C. Booth of the British Service.

Other systems, closely resembling the duplex Baudot, and incorporating features borrowed from the typewriter have since been developed, and these are likely to supplant the Baudot in the future. At the present time a large precentage of the telegraph traffic in France is carried by the Baudot system.

Transmitter. Transmission on the Baudot system is effected by means of small keyboards each having five keys similar

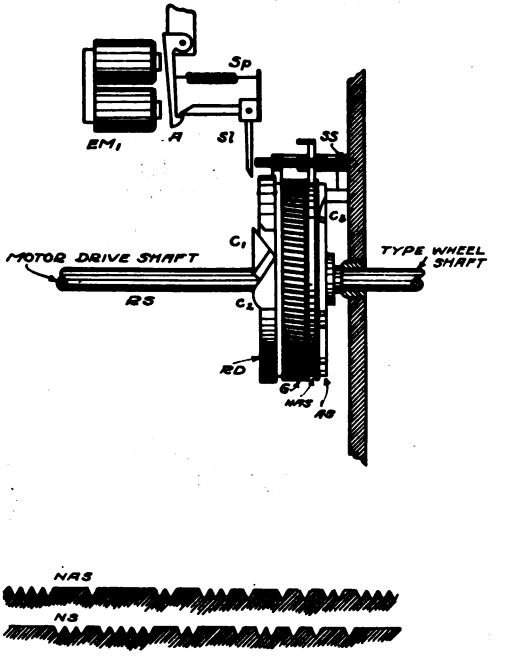

FIG. 20

to piano keys, four such keyboards (Fig. 19) being connected to a four channel or quadruple set. As the keys are depressed they are automatically locked by small hooks and remain in the depressed position until the brush has swept over the five segments of the sending ring connected to the particular transmitter. An electromagnet mounted in the keyboard is then energized by an impulse through a local ring on the distributor, and releases the hooks, at the same time producing an audible click in the transmitter. This gives a signal,

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termed the Cadence signal, to the operator who immediately depresses one or more of the keys setting up the next letter combination.

Printer. There are several types of Baudot printer, all of which are entirely mechanical except the initial actuation of the selecting magnets. In this paper it is proposed to describe briefly the salient features of the "Carpentier" type.

In Fig. 20 $E\,M_1$ represents one of the five selecting magnets connected to the receiving segments on the distributor. These five selecting magnets are mounted close together so that their armatures A and selecting levers $S\,L$ are grouped together and adjacent to their respective sliding selectors one of which $S\,S$ is shown in the figure.

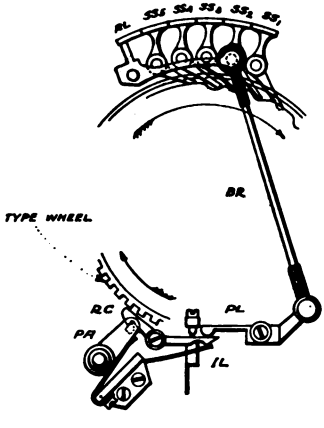

FIG. 21

When an electromagnet is actuated its armature A is pulled forward releasing the selecting lever $S\,L$. As the rotating disk $R\,D$ moves round a selecting lever which has been selected is caught by the cam C_1, and thereby is caused to press against its corresponding sliding selector $S\,S$ forcing the toe piece of the sliding selector into the channel marker $A\,S$. A selector lever which has not been actuated remains on the left side of the cam C_1, as it passes, so that its sliding selector remains with its toe piece in the channel marker $N\,A\,S$.

Immediately a selecting lever has performed its function of causing the sliding selector to be moved it is restored to normal by the cam C^2 and its upper arm is caught by the armature A.

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The rotating shaft driven by an electric motor carries the disk *R D*, the gear *G*, the disks *N A S* and *A S* and the typewheel. The disks *N A S* and *A S* are notched as shown in Fig. 20. A front view of the sliding selectors is shown in Fig. 21. Normally these sliding selectors rest with their heads abutting against each other, irrespective of whether they have been selected or not. As the disks rotate notches will pass under their toe pieces, but no movement will take place until a notch is under each toe piece. All toe pieces will then drop into the notches simultaneously, causing the heads to move together towards the right. As the disks continue to rotate the toe pieces will be sharply thrown up by an unnotched portion of the periphery, causing the heads to overshoot and strike sharply against the releasing lever *R L* (Fig. 21). Actuation of this lever causes the releasing bar *B R* to pull up the pedal lever *P L* which strikes the intermediate lever *I L*, and removes the retaining pawl from the printer arm *P A*. The printing mechanism is thereby released, the paper tape is impressed against the typewheel, and the desired character printed.

The typewheel has characters on 31/40ths of its periphery, and whilst the blank portion of 9/40ths passes in front of the printing position the printing arc is restored to normal.

Letters of the alphabet alternate with figures and symbols. When it is desired to print a figure or symbol the "figure shift" signal combination causes the typewheel to be displaced from normal equal to the angular distance between a figure and a letter, so that on receipt of the next signal combination a figure shall be opposite the paper tape instead of a letter. The typewheel is restored to normal by the "letter shift" signal combination.

The speed of rotation of the typewheel must correspond approximately to that of the distributor brushes, and provision for maintaining approximate synchronism between these instruments must be made.

The Baudot system is generally operated at 180 revolutions of the distributor per minute so that an operator sets up letter combinations at the rate of three per second. Assuming six letters per word, this is equal to a speed of 30 words per minute per transmitter or 120 words per minute for the four transmitters. The system may be operated duplex, giving a total carrying capacity of 240 words per minute. One

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circuit has been in operation for several years between London and Birmingham, giving six channels in each direction—a total carrying capacity of 360 words per minute.

Synchronism. In the Baudot system the brush holder is connected to the motor shaft through gears, and a mechanical device actuated by the correcting relay causes one of the intermediate gears to be rotated one tooth which has the effect of stepping back the brushes with respect to the driving shaft.

Multiplex With Tape Transmission and Page Printing

There are two multiplex systems of this type—the Murray and that developed in the research laboratories of the Bell System in collaboration with the engineers of the Western Union Telegraph Company. The Murray system was the forerunner in showing the advantages to be gained by the use of keyboard perforators instead of direct transmission, as in the Baudot system, and in the use of a page printer, which turns out finished messages ready for delivery, thereby eliminating the gumming process.

A two-arm Murray multiplex installation has been in commercial use in England for about ten years. The war, however, prevented the manufacture of further installations; otherwise, it is probable that complete quadruple duplex installations of this system would have been in service by this time.

The multiplex system designed in this country resembles the Murray as regards the use of perforators, page printers, and rotating distributors, but differs from it in many important details. What will be said in this paper concerning the operation advantages of the American multiplex applies generally to the Murray multiplex.

The American multiplex system, like the Murray system, is based fundamentally on the duplex Baudot system, and was developed primarily to meet the needs of the Western Union Telegraph Company. The further development of the American system, providing greater flexibility by means of forking and extending the individual arm or channel, has been developed in the research and development laboratories of the Bell System.

This system differs from the Baudot system in the following respects:

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Messages are first prepared on keyboard perforators, instead of being transmitted direct from five key transmitters. No special signals are transmitted over the line for the purpose of maintaining synchronism. Messages are printed in page form instead of on tape, thereby eliminating the gumming

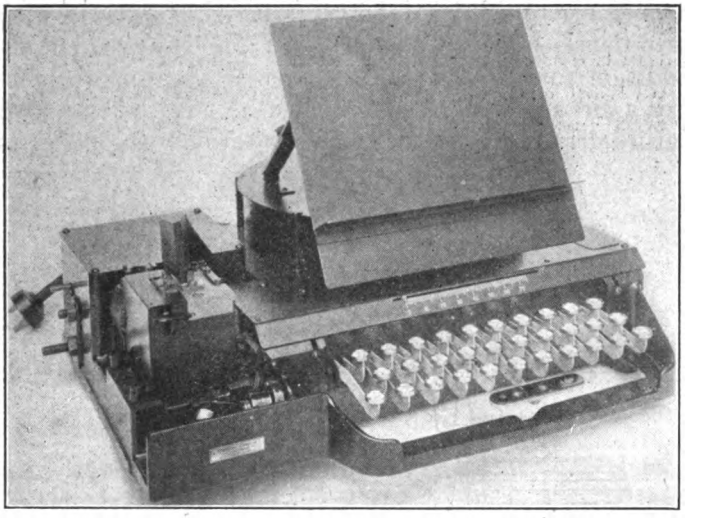

FIG. 22

operation. For a complete quadruple duplex equipment, that is, one which provides for the simultaneous transmission of eight messages—four in each direction—there is required at each end of the line:

Distributor with driving fork and impulse motor

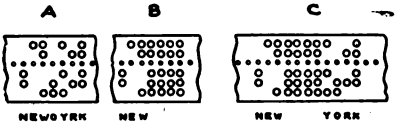

FIG. 23

Four transmitters
Four keyboard perforators
Four automatic control units
Four printers
Line and local relays, and duplex balancing equipment.

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Messages are first prepared as perforations on a tape, by means of a keyboard perforator as shown in Fig. 22. The perforations for each character are made across the tape and occupy a space of 0.1 in. per letter character. Hence a 30-word message occupies a length of only 18 inches of tape.

Perforator. The perforator comprises three rows of keys arranged according to standard typewriter practise, which control the selection of the punches. The depression of a key, in addition to effecting the selection of a group of punches, causes a circuit to be closed through an electromagnet whose armature drives the selector punches through the paper tape.

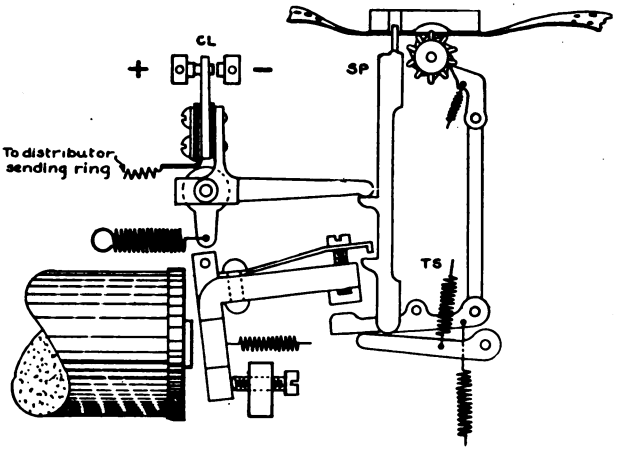

FIG. 24

Provision is made for back spacing the tape, so that in the event of an error having been made, and observed by the operator, she may cancel it in such manner that it does not appear on the printed record at the distant end. For instance, if the word New York is to be perforated, and in error, the *O* key is depressed before the *Y* key as shown at *A* Fig. 23, the tape would be back spaced and all letters back to and including the *Y* would be cancelled as shown at *B*. Then the word would be continued commencing at the *Y* as shown at *C*. This feature is referred to as the "rub-out" and permits the operator to erase errors from the tape which prevents them from appearing in the printed message.

Transmitter. The transmitter, Fig. 24, has five contact levers, *C L*, insulated from each other and controlled by five

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selecting pins, $S P$. The contact levers normally rest against a busbar connected to one pole of the line battery. These

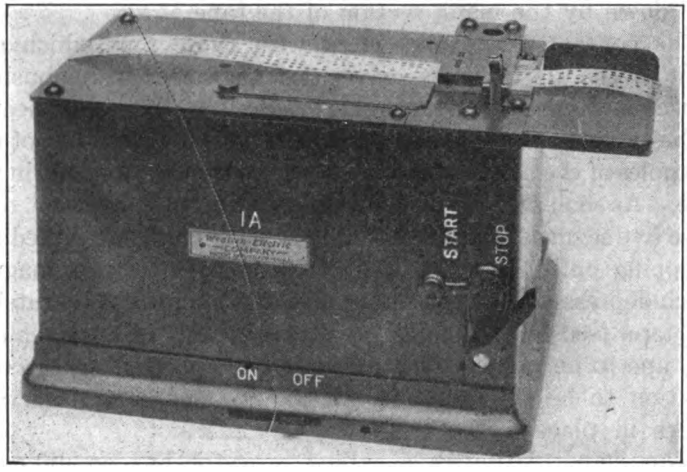

FIG. 25

contact levers are connected to five consecutive segments on the sending ring of the distributor. When a selecting pin

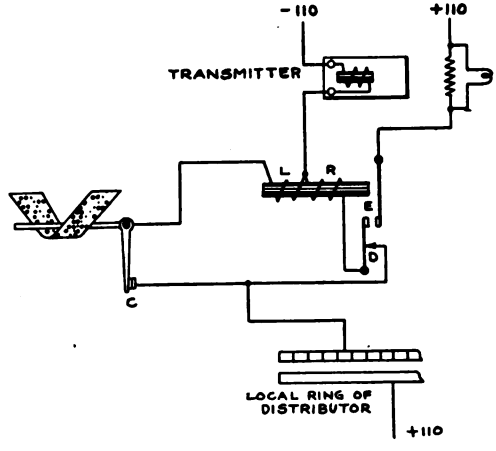

FIG. 26

rises through a signal hole in the perforated tape, its contact lever moves over and makes contact with another busbar connected to the other pole of the line battery.

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Normally each selecting pin tends to move upwards due to a tension spring, *T S*. Only those pins which find a signal hole in the tape, however, are free to rise, the others being held down by the blank section of the tape.

The contact levers associated with those pins which rise through the signal holes move over to the opposite busbar. Consequently, the five segments of the distributor connected to the transmitter are placed in contact with one or other of the two poles of the line battery according to the perforations in the tape. As soon as the brush on the distributor has swept over these five segments, a current impulse which may be termed the "stepping pulse" is made to pass through the electromagnet which depresses all the selecting pins and by means of a ratchet and tape feed wheel similar to that in the perforator, causes the tape to be stepped forward ready for the next letter combination to be set up. Fig. 25 shows the transmitter with covers in place.

Auto Stop. Although a skilled operator has no difficulty in maintaining an ample length of perforated tape between the perforator and the transmitter, conditions arise in normal operation when a perforating operator may have to suspend work temporarily. The transmitter, however, continues to feed forward the perforated tape and were no provision made, the tape would become torn as soon as the slack was taken up between the perforator and the transmitter. This is taken care of by a device, termed the "auto-stop," which consists of a light lever and a differentially wound relay connected as shown in Fig. 26. The lever is so placed between the perforator and the transmitter that the slack perforated tape sags beneath it, but does not touch it. The weight of the long arm of the lever ensures the contact at *C* being closed. The stepping pulse from the local ring of the distributor to the transmitter magnet has two paths, one via contact *C*, the other via contact *D*. Consequently, the current divides equally between the differential windings *L* and *R*, of the relay, which remains inoperative. Whenever the sag in the tape is taken up sufficiently to carry with it the contact lever, the contact at *C* is opened, so that the next stepping inpulse from the local ring of the distributor passes through one winding only of the differential relay and actuates the relay. Its armature causes contact at *E* to be made and that at *D* to be broken. The relay is therefore locked up and the magnet of

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the transmitter is energized. So long as this condition is maintained the selecting pins of the transmitter are held in the position for transmitting the "blank" signal which has no effect whatever upon the printer at the distant station.

As soon as the operator commences perforating and the slack tape allows the contact lever to drop, the first "stepping

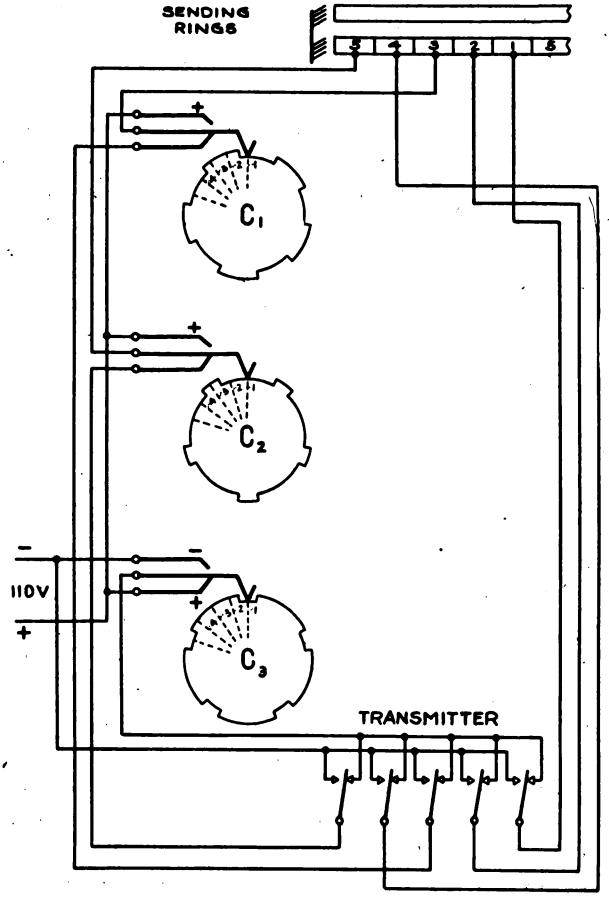

FIG. 27

pulse" will cause the unlocking of the differential relay and normal transmitting conditions to be restored.

Auto Control. While not an essential element of the system, the auto control is a desirable adjunct. In order to save time, it is advantageous to be able to signal the distant station

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operator without having to wait until a message in course of transmission has been completed, and it is essential that such signals shall not involve mutilation of the printed record of such message.

This is secured by means of the "auto control" device which is connected in the circuit between the transmitter and the sending ring of the distributor. The "auto stop" feature is incorporated in this device, the circuits being inter-connected, but for the sake of clearness the auto control circuit alone is shown in Fig. 27.

The auto control, therefore, is a device for automatically stopping the transmission of a message and for sending over the line the necessary signals to ring a bell mounted on the printer, at the distant station. Provision is made for ringing the bell once, twice, up to five times in succession. A code of signals can be used. For example:

1 ring may mean "stop"
2 rings " " "rerun last message"
3 rings " " "repunch " " "
4 rings " " "start"
5 rings " " "attendant" or "supervisor."

The auto control consists of a starting sector or handle with five finger positions, connected to a small spring motor, three cams rigidly mounted on a spindle, acting upon three separate groups of contact springs and an escapement wheel controlled by an electromagnet as shown by Fig. 28. The starting handle is actuated by inserting a finger in one of the five finger positions and pulling it forward to its starting position which is determined by a finger stop. The spring motor is wound up by this forward movement and when the finger is removed, the motor causes the spindle carrying the three cams to be rotated, at the same time restoring the handle back to normal position. The "stepping pulses" which normally actuate the electromagnet of the transmitter are diverted so as to actuate the electromagnet controlling the escapement wheel of the auto control device so that the cams are rotated one step for each "stepping pulse."

In order that the circuits may be readily traced, dotted lines have been drawn to show the position of the middle springs on the cams at each step. The normal position of the springs is shown in Fig. 27.

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The first step, that is, to position marked No. 2; causes the middle spring of cams 1 and 3 to be raised. The polarity of the right hand contacts on the transmitter is changed from

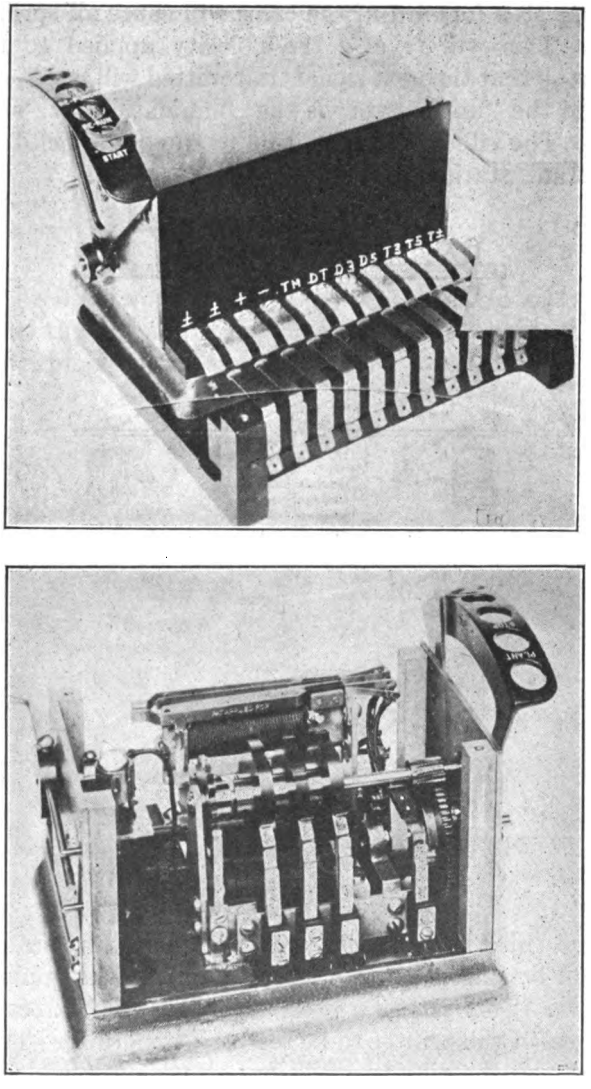

FIG. 28

positive to negative by the action of cam 3 whilst the actuation of the spring on cam $C1$ causes segment 3 on the sending ring to be connected to the positive line battery, irrespective

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of the polarity applied to the third contact lever of the transmitter. Consequently, the five segments will send − − + − −, which is the "figure shift" signal. This will actuate the printer at the distant station and adapt it for "upper case" operation. The next step forward of the cams will cause all springs to be raised. This will reverse the polarity applied to the fifth segment so that the next signal transmitted will be − − + − +, which in the "upper case" is the combination for "signal" or "bell." The effect of this will be to cause the bell to ring at the distant station printer.

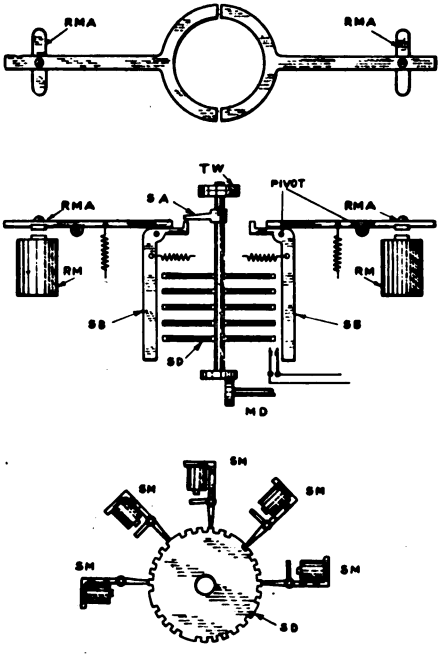

FIG. 29

At the third step of the cams, the middle spring of cam 3 only will be raised, so that negative voltage is applied to all segments. This is the "letter shift" signal and causes the typewheel of the printer to be restored to normal. The fourth step restores the circuit conditions to normal ready for transmitting direct from the transmitter.

This cycle of operation is repeated one, two, three or fou times, according to the setting of the handle. None of the signals transmitted by the auto control device actuates the

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spacing or lateral movement of the paper carriage so that the auto control may be operated whilst the printer is in

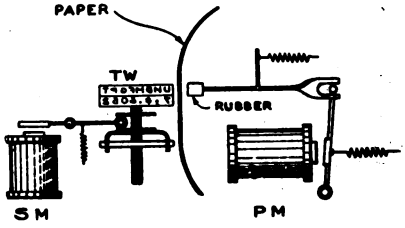

FIG. 30

the middle of a word. When the auto control signals have been sent, the normal transmission of the message continues, and the printer completes the unfinished word.

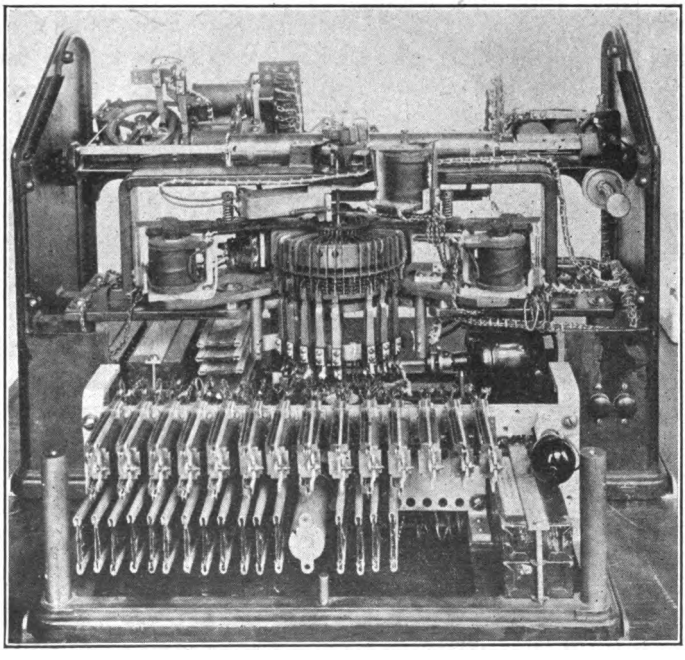

FIG. 31

Printer. The printer is of the movable paper carriage type, and all operations such as causing the paper carriage to be

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returned for the printing of a new line and moving the paper upwards equal to the distance between lines, are performed automatically under control of signals from the sending station.

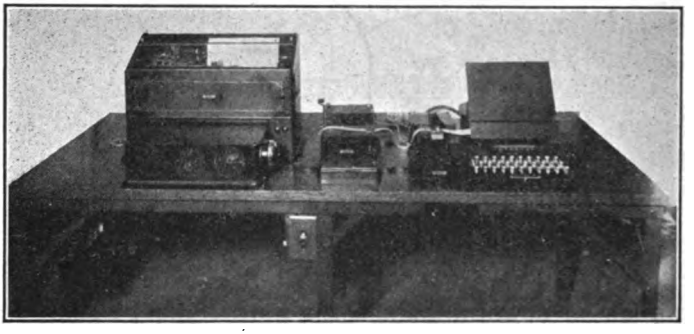

FIG. 32

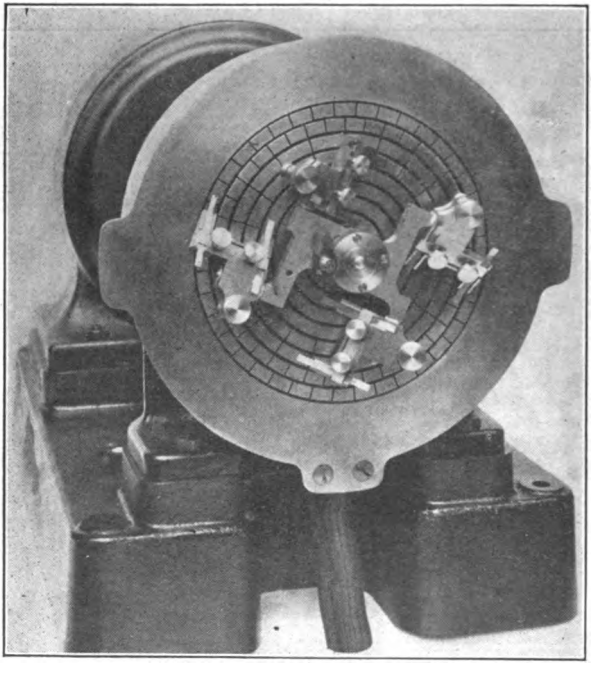

FIG. 33

A typewheel *TW*, Fig. 29, mounted on a vertical shaft, is made to rotate by means of a small electric motor. Projecting from the typewheel shaft is a short arm *S A*, the free end

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of which just clears the ends of the selector bars *S B*. When stopped by a raised selector bar, the typewheel is so positioned as to print the particular letter associated with that selector bar. Normally, the selector bars are held down by the semi-circular ends of the armature levers *R M A* of two release magnets *R M*, Fig. 29.

The five horizontal selector disks are mounted around a hollow drum or shaft enclosing the typeshaft. Each disk has notches so arranged around its periphery, that when one of the disks is moved through a small angle, a notch on each of the disks will be in vertical alignment so as to permit the vertical leg of one selector bar to move inwards. If two disks are moved, the alignment of notches will occur opposite another selector bar, if three disks are moved the alignment will take place opposite still another selector bar and so on. With five selecting disks, 32 possible selections are available. There are 31 selecting bars, each one of which is associated with a character to be printed, or contacts to be closed to cause one of the several functions which the printer has to perform. One selection is not used, since it is desirable to have one combination which will cause no operation in the printer. The selector bar on the right, Fig. 29, is shown as a function or "stunt" bar. These functions are "space," "carriage return," "line feed," "figure shift," "letter shift" and "bell."

The typewheel is mounted on the typeshaft in such a manner that it may be raised so as to bring a second row of characters opposite the printer hammer. This operation is performed by means of the shift magnet *SM*, as shown in Fig. 30. When the "figure shift" signal is received, a "stunt" bar is selected and closes the contacts of the shift magnet *SM*. When the "lettershift" signal is received, another "stunt" bar is selected, which opens the circuit of the "shift magnet" and the typewheel is brought down to its normal position.

The paper on which the messages are printed is fed round the platen of the paper carriage which slides laterally on a square shaft. Fig. 31 shows the printer with all covers removed. Fig. 32 shows an operating table with all equipment in position.

Distributors. The distributor face plate consists of eight rings, four being solid and four segmented, as shown in Fig. 33. The rings are associated in pairs, one segmented and the other solid. The two brushes which sweep over the two rings of

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a pair are in electrical contact with each other so that the solid ring is connected in sequence to all the segments of its associated ring, once per revolution. The outer or receiving ring has 40 segments and is associated with the fifth ring. The second or correcting ring (40 segments) is associated with the sixth ring. No. 3 is the sending ring (20 segments) and is associated with No. 7. The innermost segmented ring (20 segments) is termed the "local" and is associated with

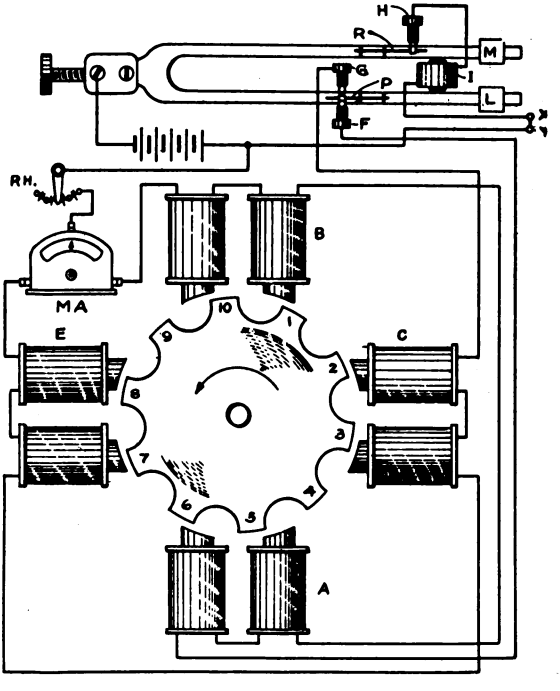

FIG. 34

the innermost solid ring. The brushes are made from thin copper wire and make contact on one segment only at a time. They are mounted on a balanced brush holder which is carried by a spindle projecting through the center of the face plate.

Two types of distributors have been designed, one in which the brush holder spindle is directly connected to the shaft of the driving impulse motor and the other in which intermediate gearing is introduced between these parts, for a purpose which will be described later.

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The La Cour or phonic wheel motor together with the electrical driving fork is shown in schematic form in Fig. 34.

The fork carries two contact springs R and P in electric contact with the fork itself. Mounted below the tines of the fork is an electromagnet I for causing the fork to vibrate. When the tines are not loaded with weights M L the fork vibrates at the rate of approximately 55 cycles per second. If a slower rate is desired, weights are fixed on the tines as shown in the figure. The rate of vibration can be varied between 25 and 55 cycles by this means. Provision is made

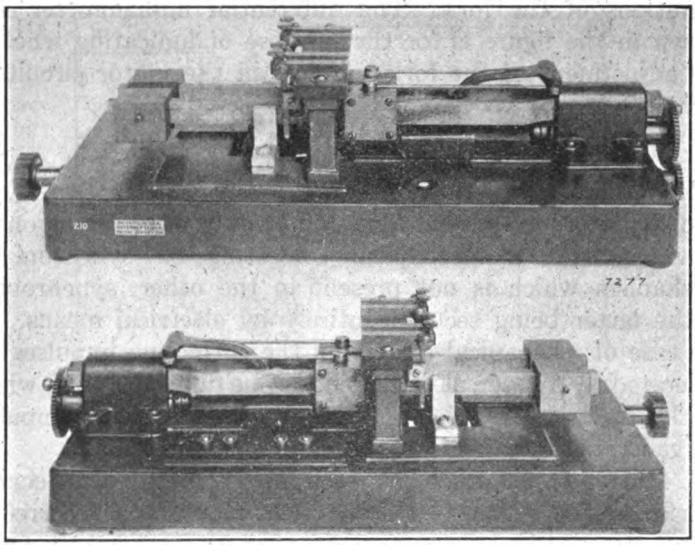

FIG. 35

for effecting small changes in speed, by means of additional weights near the base of the fork, which are so mounted as to be slidable along the tines by an adjusting screw operated by a handle or knob at the end of the fork. This adjustment can be made whilst the fork is in vibration. A photograph of the fork is shown in Fig. 35. In the case of a quadruple or a four arm installation, the speed of the fork in cycles per second corresponds to the speed of operation of each channel in words per minute, so that if the fork vibrates at 50 cycles per second each transmitter operates at a speed of 50 words per minute.

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The phonic wheel motor has an armature so shaped as to form ten teeth or polefaces, equally spaced, around the periphery. Mounted 90 deg. apart are four electromagnets with polefaces shaped so as to be concentric with the edge of the polefaces or teeth on the armature.

The electromagnets diametrically opposite are connected so that *A* and *B* (See Fig. 34) are energized together and *C* and *E* together. Consequently, when the fork is vibrating, *A* and *B* will be energized alternately with *C* and *E*. The number of the polefaces on the armature is such that the armature makes one complete revolution during ten complete vibrations of the fork. The differential milliammeter *MA* shown in the figure is for the purpose of indicating whether the adjustment of the fork contacts in the motor circuits is correct.

SYNCHRONISM

Mechanical Correction. As previously stated two types of distributors are used. They differ only in so far as one is provided with a mechanical correcting or synchronizing mechanism which is not present in the other, synchronism in the latter being secured entirely by electrical means. In the case of mechanical correction the correcting impulses are generated by a reversal of current in one direction only, whilst in the electrical correcting method the correcting impulses are generated by current reversals in both directions.

A schematic diagram of the circuit for mechanical correction is shown in Fig. 36. The distributor motor at the corrected or speed controlled station is arranged to run slightly faster than the motor at the correcting or speed controlling station. If reversals of current in the line signals take place when the brushes which sweep over the correcting rings at the controlled station are on a dead or unconnected segment, as at the point indicated by the arrow marked *X*, no correction takes place. But the brushes at the speed controlled station will gain over those at the speed controlling station so that after one or two revolutions the brushes at the former station will be leading, and be on a "live" segment at the moment when the corrector relay tongue which follows the movements of the line relay, moves to its *M* contact.

Before the "break" relay *B R* has had time to pull up its armature, an impulse passes via the back contact of *B R* to

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the solid correcting ring, across the brushes, the "live" segment, switch S through the correction relay $C\,R$ to the $-110\ V$. The corrector relay is actuated and is locked up due to current from the $+110\ V$ flowing via the armature and front contact of $C\,R$ and the back contact and lever on the stepping pawl P. A path is also provided from the +110 through the corrector

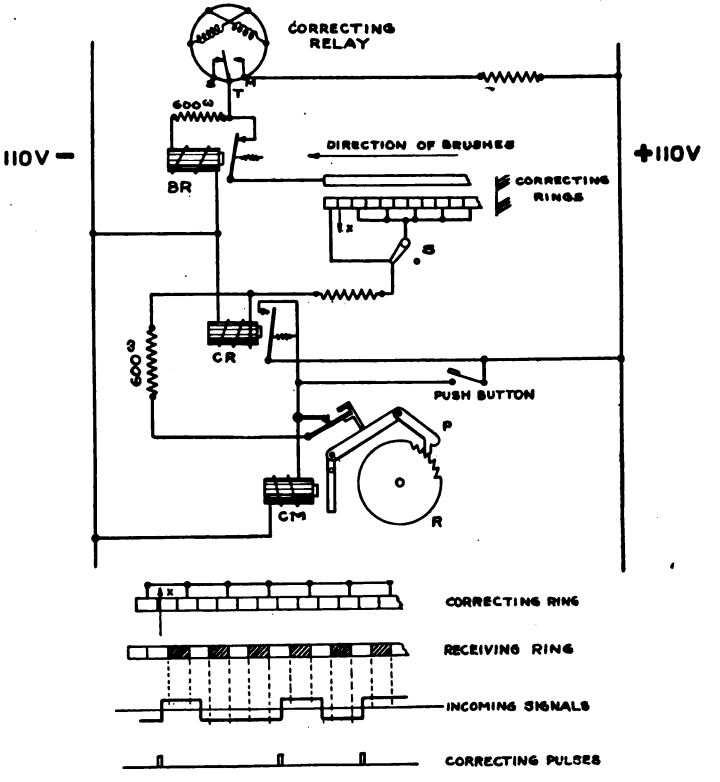

FIG. 36

magnet $C\,M$ which is energized. Actuation of the armature of $C\,M$ causes the pawl P to step the ratchet wheel one tooth. As it completes its stroke the pawl lever causes the circuit from the +110 to be opened so that the corrector relay $C\,R$ and the corrector magnet $C\,M$ are restored to normal. The stepping of the ratchet wheel has the effect of momentarily stopping or retarding the movement of the brushes so that they are again in sufficiently close phase relationship with the incoming signals to insure the correct distribution of the electing impulses to the printer selecting relays.

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The mechanical feature of the correcting device is shown in Fig. 37. The motor shaft carries with it the frame *F* on which is mounted the corrector magnet, the ratchet wheel *A*, gear wheel *B*, the pawl and jockey roller.

A and *B* are fixed on the same spindle and are prevented from rotating by the jockey. Consequently, when the motor shaft is rotated, gear *B* transmits motion to the brush holder shaft in the direction indicated by the arrow marked *N*. When a correcting impulse actuates the corrector magnet, the pawl steps the ratchet wheel *A* one tooth in a counter-clockwise direction, so that *B* advances one tooth around *C* in the direction marked *N*, which is the equivalent of stepping the gear *C* in the direction marked *R*. The resultant effect is that the brush holder shaft is momentarily retarded.

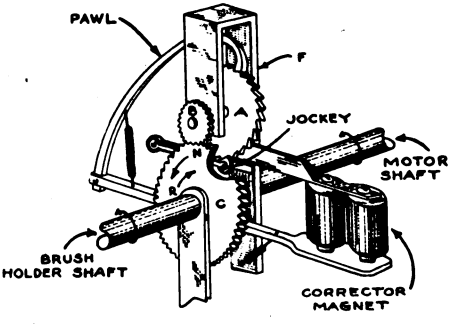

FIG. 37

Phase Finding. In order to bring the brushes at the two stations into proper phase relationship, *i. e.* into synchronism, a switch is provided at the speed-controlling station for sending a long negative pulse from sending segments 1 to 19 and a positive pulse from sending segment 20. The switch marked *S*, Fig. 36, at the speed-controlled station is thrown to the right, disconnecting all the "live" segments but one. Consequently, only one correcting pulse will be generated per revolution of the brushes and it will be inoperative until the brushes at the corrected station overtake the incoming signals, at the position marked *X*.

Electrical Correction. Fig. 38 shows in schematic form the circuit arrangements for electrical correcting. A distributor arranged for electrical correction has the impulse motor

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directly connected to the brush holder and correction is effected by altering the speed of the fork which determines the speed of the motor. When the resistance R is in series with the electromagnet of the driving fork at the speed-cor-

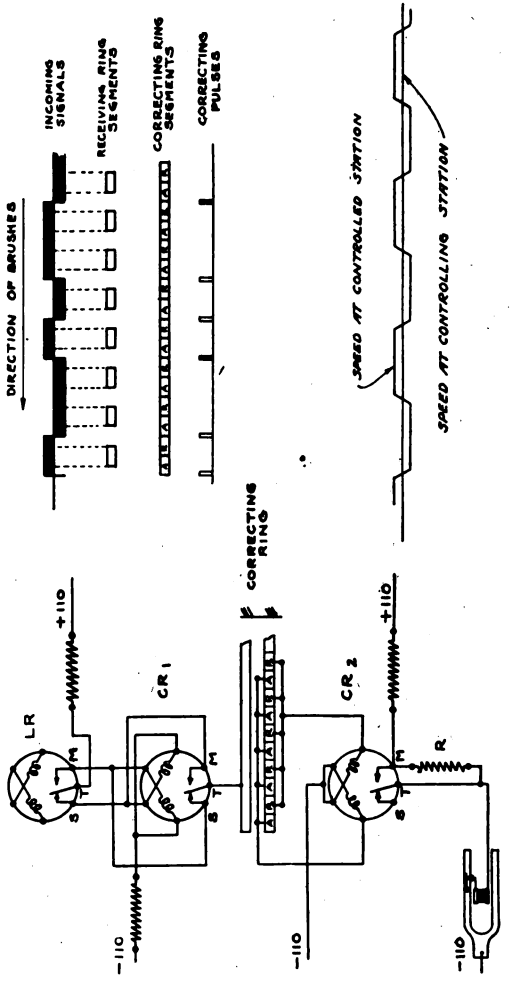

Fig. 38

rected station, the speed of the fork is slightly faster than that of the fork at the speed-controlling station, and when R is short-circuited the speed of the fork is slightly lower than that of the fork at the other station. The function of the

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correcting impulses which are generated from the signals themselves, is, therefore to control the speed of the fork by means of the resistance R. The tongue of the corrector relay CR_1 follows the movements of the tongue of the line relay $L\,R$, but with a slight lag. Consequently, if the line relay tongue moves to its M contact, there will be a circuit from the $+$ 110V, the tongue and contact M of the line relay, contact S and the tongue of No. 1 corrector relay CR_1 to the solid correcting ring, across the brushes to the segmented ring. If the brush is on an A segment the correcting impulse will flow through the left-hand winding of the No. 2 corrector relay CR_2 to the $-$ 110V. If the tongue of No. 2 corrector relay happens to be on its M contact, it will move to its S contact, thereby inserting the resistance R in the fork circuit and speeding up the frequency of the fork vibrations. The motor will consequently be rotated at a slightly faster speed so that by the time the brushes have swept over several segments, they will be on an R segment at the moment a reversal occurs in the incoming signals and a correcting impulse is generated. Such correcting impulse would flow through the right-hand winding of the No. 2 correcting relay and cause its tongue to move to the M contact. The resistance R would be shunted out and the speed of the fork reduced. The brushes of the distributor are therefore always either leading or lagging but the frequency with which correcting impulses are received prevents the amount of lead or lag to be so great as to detrimentally affect the impulses which pass via the shortened segments of the receiving ring to the selecting relays of the printers.

Phase Finding. Proper phase relationship between the brushes in the case of the electrical correction method is secured by the speed-controlling station sending one complete current reversal per revolution, that is, positive current from segments 1 to 10 and negative current from segments 11 to 20. At the speed-controlled or correcting station, the connections to the segments of the corrector ring are altered, segments 1 to 20 form one big A segment and segments 21 to 40 one big R segment. The connection to the M contact on the No. 1 correcting relay is opened so that correcting impulses will be generated when the signal current polarity changes from negative to positive only. Consequently, there is only one position on the correcting ring where correction will take place and the brushes will either gain or lose with respect to

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the incoming signals, according as they are on the *A* or the *R* segment, until they are in synchronism, when correction will commence. All switches are then turned to normal.

Margin. The outer or receiving ring is mounted so as to be free to be rotated. This is for the purpose of placing the segments of the receiving ring in such a position with respect to the segments of the correcting ring that the middle portion of each signal shall be used for selecting purposes. Once synchronism has been secured, all switches at normal and the distant station transmitters turned off, each of the four printers will be receiving the "blank" signal. By moving the receiving ring in a clockwise direction until false signals are received, and then moving it in a counter-clockwise or opposite direction until false signals are again received, the midpoint between these two positions indicates the correct position for reception. The distance between the two positions where false signals are received is an index of the working margin.

In order that synchronism shall be maintained when all transmitters are turned off, the line battery connections of the first and third transmitters are reversed, so that four reversals of current will occur per revolution of the brushes, and provide the necessary correcting impulses at the receiving end.

The connections to the first and third printers are adapted to meet these changes of battery at the sending end.

Operating Features and Economic Aspects

The function of a telegraph system is to provide a means for the prompt and accurate transmission and reception of communications as economically as possible. The merits of various telegraph systems can therefore be considered under the following heads:

1. Speed of Service
2. Accuracy
3. Operator Output
4. Maintenence
5. Line Economics
6. Flexibility of System

Speed of Service

By this term is meant the average time taken in handling telegrams from the moment an operator at Station *A* commences to perforate or to send a message until it is ready at Station *B* for transference to some other part of that office,

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either for delivery or for retransmission over another circuit. Messages for delivery by messenger have to undergo further handling. As such further handling, however, is not directly associated with or affected by the system of transmission over the wires, time occupied in this connection is not included.

Reviewing the methods of operation of the various systems under consideration, it will be shown wherein time losses, which occur in the high-speed systems, are avoided in the multiplex.

At the Sending End. In the high-speed systems messages are first prepared by perforating operators, seated conveniently near to the transmitting operator who feeds the perforated tapes into a high-speed transmitter. In order that as little time as possible be lost by the perforating operators in passing the message forms with the corresponding tapes to the transmitting operator, it is the usual practise to perforate two or three messages on each tape. If such tapes are immediately fed into the transmitter, the first message has already undergone a delay equal to the time taken to perforate all three messages and the second message has undergone a delay equal to the time taken to perforate the second and third messages. The transmitting operator, however, has no time to sort out the tapes from the various operators so as to transmit messages in their exact order of priority. It usually happens, therefore, that a certain proportion of the messages undergo further delay before actual transmission takes place. It may be taken that the average delay in the case of high-speed systems is not less than three minutes.

With a multiplex system transmission over the lines takes place almost immediately the keys are actuated. In other words a multiplex provides practically direct connection between operator and operator, as is the case with Morse working.

At the Receiving End. There is not much difference between the high-speed and multiplex systems as regards speed of service, a slight advantage, however, resting with the multiplex.

Unfortunately, telegraph traffic does not glide along as smoothly as has been outlined above. Errors creep in and must be corrected. With the high-speed systems, a correction operator is required at each end of the circuit. Messages dealing with the correction of errors pass between these operators and although given priority over other traffic several

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minutes elapse in their transmission in each direction. Therefore, before an inquiry regarding a message can be received, a considerable number of other messages will have been transmitted, and unless these messages have been arranged in numerical order, some time is needed to trace the required message. Further delay will occur in the transmission of the answering message so that the total delay to a message in which a correction is required may amount to many minutes.

With the multiplex systems the mode of working admits of such corrections being asked and obtained almost instantly.

In a paper read before the Post Office Telephone & Telegraph Society, London, on November 24th, 1913, Mr. John Newlands, Controller of the Central Telegraph Office, states

> There is no doubt that all existing systems of telegraphy which involve the preliminary punching of each message tend to create delay, because even when the punching operation is completed, the message is not yet on its way, the process of transmission through the transmitter has still to be carried out, and when there are two messages on each slip, and each separate slip must perforce await its turn—there is always an appreciable loss of time, which does not take place, for example, on the Baudot System nor even in Morse Keying.

It is interesting to note that this advantage of multiplex operation has been recognized in England and an effort has been made to adapt the Wheatstone System to the multiplex principle, so far as transmission is concerned. The arrangement is as follows:

Beside each perforating operator is a motor-driven Wheatstone transmitter. These transmitters are connected to an electromagnetic rotary switch which is arranged to switch the line to each transmitter in sequence. The switch is actuated by a signal from the transmitter to which it is connected, each actuation transferring the connection to the next transmitter. When perforating operator No. 1 completes a message, he depresses a special key on the perforator which perforates a hole in the tape, not in alignment with the signal holes. As this hole passes through the transmitter, it causes actuation of the switch, which stops the motor of the No. 1 position transmitter and starts the motor of the No. 2 position transmitter, at the same time switching the line from No. 1 to the No. 2 transmitter. Similar operation at the end of the message transmitted by the No. 2 transmitter switches the line to the No. 3 transmitter and so on in rotation.

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It is doubtful if such a scheme will prove satisfactory, however. Messages are not of uniform length, nor do operators perforate at exactly the same speed. It effects the elimination of the transmitting operator, but it is difficult to see wherein much improvement can be secured towards providing a quicker speed of service. The use of two or more high-speed transmitters which are operated intermittently involves added complexity and cost to the sending end apparatus.

Accuracy of Printing Telegraphs

Whatever may be the system of telegraphy employed, the standard of accuracy is dependent upon the care with which the messages are checked. In Morse working, the receiving operator is expected to check the accuracy of a message whilst performing the mental operation of translating the dots and dashes into letters and the physical operation of recording them on a typewriter. Actually three functions are performed simultaneously:

1. Translating telegraphic signals into letters, mentally.
2. Operating a typewriter, selecting correct keys.
3. Scrutinizing the typed copy to see that it contains no errors.

Although it has been claimed that the two first operations are performed entirely automatically by skilled operators, such is not the case except in rare exceptions. If a function is being performed automatically, that is, requiring no attention of mind, then the mind can be employed on some other function. It is only necessary to request a Morse operator to read some message other than that he is in the act of receiving, or to engage him in conversation to show how little attention he is able to give it, without interfering with his main task. Psychological authorities agree that if the mind be engaged in two or more independent actions the principal action is hampered by the side issues.

Apart from its being a slower process than Morse sounder working, the translation of telegraph signals from a tape as in the Wheatstone system involves a division of attention between the tape and the sheet on which the message is being written or typed with the result that the liability to making errors is increased. When continued for a long period it also tends to produce eye strain.

A page-printing system necessitates only the checking of the messages, and consequently that work can be given un-

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divided attention by the operator, with the result that it is done better.

It may be of interest to mention that a European telegraph administration, desirous of securing data in regard to undetected telegraphic errors, caused a careful examination to be made of a large number of messages which were handled by different telegraph systems. This examination showed that the number of undetected errors per 100 messages was as follows:

Morse tape recording.. 0.11
Morse sounder 0.09
Hughes printer 0.04

It is understood that the introduction of the multiplex printing system in the Western Union Service has resulted in a proportionate improvement as regards accuracy, closely approximating these figures.

When it is realized that telegraphic errors oftentimes result in financial loss, as well as involving considerable expense in official correspondence and investigation, the greater accuracy secured by a printing system must be regarded as an important factor in its favor.

OUTPUT

The introduction of printing telegraphs in place of the Morse has not resulted in so great a percentage gain in operator output as has been achieved by the use of automatic machines in other fields of activity, nor can they ever be expected to do so. The human factor cannot be eliminated entirely; every message must be handled—letter by letter—by the sending operator, and be checked at the receiving end by the receiving operator.

The keyboard perforator, however, has been responsible for a considerable increase in speed of working at the sending end, whilst at the same time its operation involves less mental and physical fatigue on the part of the operator.

At the receiving end of a printing system, the operating duties are less exacting than those of the Morse operator. Although messages must be handled without delay the nature of the work permits of a freedom to the operator which cannot possibly be felt by Morse operators. Consequently, the operators are under less mental strain and can handle a larger volume of business.

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It has been found that, in general, printing systems have shown some improvement over the Morse and Wheatstone systems, as regards labor economies.

The following statement, extracted from Mr. John Newlands' paper previously referred to, gives the comparative results of tests of various systems of telegraphy in England. As British messages average 24 words, whilst American messages average 30 words, I have equated the figures to American messages, as shown below:

System	Average per Operator Hour	
	British Messages	American Messages
Baudot Multiplex	43	34.4
Wheatstone with Creed	35	28
Morse Sounder	31	24.8
Wheatstone	26	20.8

The Siemens & Halske and American Multiplex Systems have been installed in the London office since Mr. Newlands' paper was written. No results have yet been published concerning these systems.

In the foregoing statement are shown the four systems of telegraphy by means of which probably 95 per cent of the British telegraph traffic is carried.

The multiplex Baudot shows an output per operator of 23 per cent greater than the high-speed system—the Creed, despite the fact that the Baudot sending operators are limited to a maximum speed of 30 words per minute. Assuming an increase in output pro-rata with the increase in speed resulting from the use of the keyboard perforators and automatic transmitters, say 45 words per minute, the output per operator would be 64 British messages or 51.6 American messages per hour.

All these foregoing figures refer to team work on one or more circuits.

In the 1919 April issue of the "Western Union News," some interesting records of work done on keyboard perforating machines by female operators are given. From 100 to 130 messages per hour have been perforated by a number of operators for short periods, up to eight hours. For periods covering from one month to one year, the hourly average range between 60 to 79 messages.

In one particular case a female operator maintained an average of 74 messages per hour for a period of eight hours

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during the first month after graduation from the training school.

In the same magazine is given data pertaining to record performances of Morse operators which compare very favorably with the work of the keyboard perforator operators. In order to achieve such results, however, it is necessary that the operators at both ends of the circuit shall be experts whereas in automatic operation the transmitting operator output is not limited by the skill of the receiving operator.

MAINTENANCE

Available information regarding the cost of maintaining installations of the various systems described is unfortunately too meagre to be of value in making direct comparisons.

Printing telegraph machines have not yet reached that stage of perfection where they never get out of adjustment and never have broken parts. Consequently, provision should be made for the removal of faults due to such causes as promptly as possible. What is even more important, however, is the provision of means for the detection of incipient faults before they have developed sufficiently to interfere with operation and for the quick restoration of service when it has been interrupted by an apparatus fault. In this respect, the multiplex systems are superior to the high-speed systems. For a quadruple duplex installation, it is necessary to provide only one spare instrument of each kind, except the distributor. In the case of the American multiplex system, such spare apparatus is mounted on a test table, which is provided with a small local distributor so that the machines may be tested in operation under conditions even more severe than in actual service. Spring clips are used for effecting the electrical connections on the operating and test tables and any machine can be removed and another placed in its stead in a few seconds. If the test table is located in close proximity to the operating tables, interruption to the flow of traffic due to machine trouble can therefore be almost entirely eliminated. A fault in any of the machines, except the distributor, will stop the flow of traffic in one direction over one channel only. Faults in the distributor are of rare occurrence. Generally a spare distribution face is available, and can be substituted in a few minutes.

In the case of high-speed systems an apparatus fault in the

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transmitting or receiving apparatus causes total suspension of traffic flow in one direction, and generally involves temporary interruption to the traffic in the other direction whilst the distant station is being advised of the trouble.

The percentage of spare apparatus must obviously be greater than in the case of the multiplex systems, except where four or more high-speed installations are in service in one office, and in such cases it is practically impossible to effect apparatus changes so quickly as can be done with multiplex machines. Where a complete spare set of machines is provided, it is possible, of course, to switch over to the spare set without much delay.

One important factor in connection with the maintenance of apparatus is the periodical inspection and overhaul. Such inspections reveal incipient faults. The test table and local distributor of the American multiplex system are particularly valuable for this purpose, as the more severe conditions under which the machines can be tested will reveal small defects or faulty adjustments before such defects make themselves felt under normal working conditions.

For example, if a printer operates at 65 words per minute during one inspection test, and only 60 words per minute at the next, it is an indication that some slight fault exists, which can be detected and remedied before it affects the machine at normal working speed of 50 words per minute.

Provided a properly organized system of periodical cleaning and testing is introduced, it is possible to maintain a service practically free from interruption due to apparatus troubles.

The most satisfactory method of maintaining such apparatus in correct adjustment is to specify spring tensions, distance of movement of relay armatures, airgaps etc. and to use suitable gauges for indicating whether the adjustments of the various units are within the specified limits.

Line Economies

In the synchronous type of printing telegraph systems no spacing between signal combinations is required and consequently the code is considerably shortened as compared with the Morse where the spacing between letters is equal to three dot lengths. From studies which have been made it has been found that the average signal combination in the American Morse code is equal to eight dots, and that in the continental

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Morse code nine dots. In the synchronous systems the signal combinations are all five-dot lengths. As the dot is the unit of length these codes are generally referred to as eight, nine and five-unit codes. The advantage of a shorter code can perhaps best be illustrated by example. Assuming that

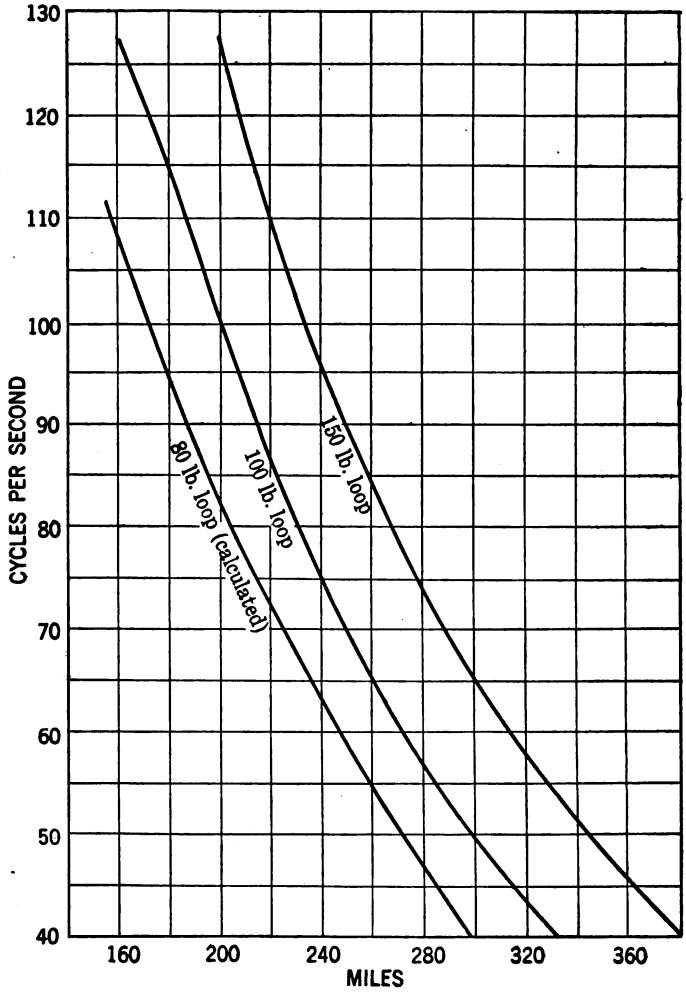

FIG. 39—METALLIC LOOP CONDUCTORS
Curves showing relation between conductor weight, mileage and speed of transmission.

over a particular telegraph circuit a maximum transmission speed of 45 cycles per second can be obtained. This speed of transmission will provide a carrying capacity of 100 words per minute for a nine-unit code, 112.5 words per minute for an eight-unit code and 180 words per minute for a five-unit code. Should the traffic load be such that 100 words per

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minute will be sufficient to carry it then the transmission speed of the five-unit code system may be reduced to 25 cycles per second. This reduction in speed will permit of operation under adverse weather conditions which tend to disturb the duplex balance, and which would necessitate a reduced speed of working on systems using an eight or nine-unit code. The author has no data as regards actual transmission speeds over aerial lines of different lengths, but in Fig. 39 are shown the results of speed tests of underground cable circuits, which were made in England several years ago.

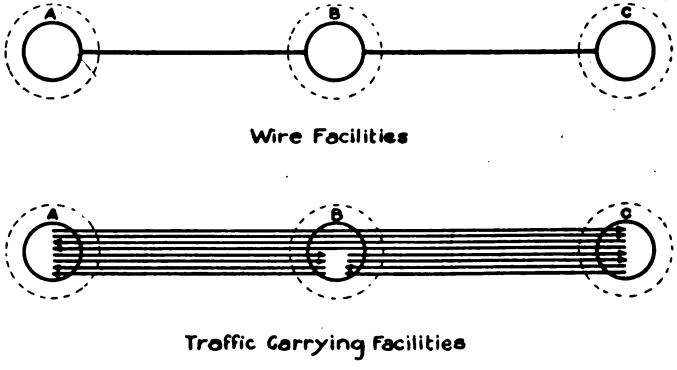

FIG. 40

It will be seen that over a metallic return circuit of 270 miles in length having copper conductors each weighing 150 lb. per mile, a transmission speed of about 80 cycles per second is secured. This would provide a carrying capacity of 177 words per minute with a system using a nine-unit code. With a system using a five-unit code an equivalent carrying capacity in words per minute can be secured by a transmission speed of 44 cycles per second, and with the same gauge of conductors this speed can be obtained over a circuit of approximately 364 miles in length, or. if 100-lb. conductors be used, over a circuit of 318 miles in length.

From the speed test figures it has been calculated that a transmission speed of 44 cycles per second could be secured over a 270-mile metallic circuit having conductors of about 75 or 80 lb. weight per mile. Assuming the wire to cost 20 cents per lb., there would be a capital saving in copper of $7560 on a 270-mile circuit, by using a five-unit code instead of a nine-unit code.

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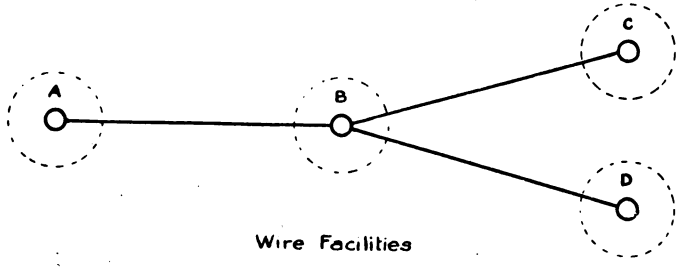
Flexibility. An outstanding feature of the multiplex system is the flexibility which it provides in linking up a number of offices with a minimum of line plant. Fig. 40 shows two quadruple duplex circuits radiating from a repeater at station *B*, and providing the following communications:

2 Channels *A* to *B*	2 Channels *B* to *C*
2 " *A* to *C*	2 " *C* to *B*
2 " *C* to *A*	2 " *B* to *A*



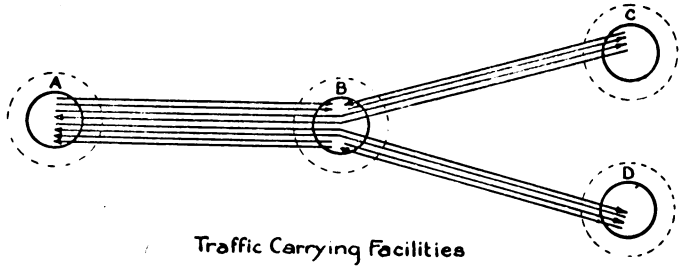


FIG. 41

Another arrangement is shown in Fig. 41 which represents a quadruple duplex circuit between *A* and *B* linked up with two double duplex circuits between *B* and *C* and *D*.

This arrangement will provide direct communication between all offices as indicated:

2 Channels *A* to *B*	2 Channels *B* to *A*	1 Channel *B* to *C*
1 " *A* to *C*	1 " *C* to *A*	1 " *C* to *B*
1 " *A* to *D*	1 " *D* to *A*	1 " *B* to *D*
		1 " *D* to *B*

A third arrangement is that shown in Fig. 42 in which the four arms of a quadruple are shown extended to four duplex printer circuits radiating from one terminal station.

By this means direct communication can be provided between station *A* and four small stations *C*, *D*, *E* and *F*, neither of which perhaps may have sufficient traffic to warrant a direct wire to station *A*.

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The duplex printer referred to is a two-channel system using practically the same apparatus as the multiplex, and a small distributor in which the brushes rotate once per letter combination transmitted. No synchronising arrangements are required, and as the brushes are momentarily stopped when they reach the normal or rest position the system has been appropriately termed "The start-stop system."

It will be obvious that by the combination of quadruple or

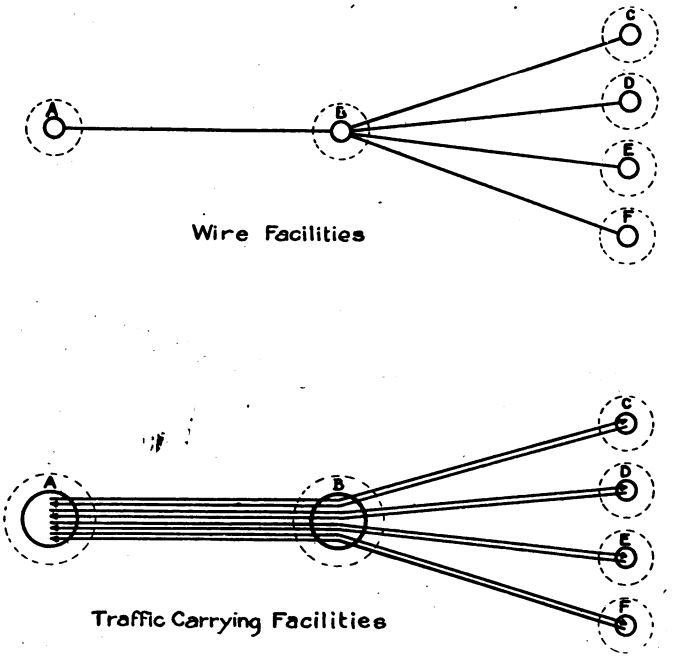

FIG. 42

double-duplex multiplex and "start stop" installations it should be possible to effect considerable economies.

In addition to the financial savings such circuit combinations help to accelerate the service by reducing the number of times a message is handled, and this in turn tends towards a higher standard of accuracy.

We cannot anticipate the transmission of all telegrams by connecting the originating office with the office of destination as is done in telephone practise but the multiplex in conjunction with the "start stop" will materially help towards developments along such lines.

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